STATE OF CONNECTICUT.

ELEVENTH ANNUAL REPORT

OF THE

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1898

Printed by Order of the General Assembly.

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The Station is located at Mansfield (P. O. Storrs), as a department of the Storrs Agricultural College. The chemical and other more abstract research is carried out at Wesleyan University, Middletown, where the Director may be addressed.

CONTENTS.

Report of the Executive Committee.

To His Excellency GEORGE E. LOUNSBURY,
Governor of Connecticut.

In accordance with the resolution of the General Assembly concerning the congressional appropriations to Agricultural Experiment Stations, and an Act of the General Assembly approved March 19, 1895, relating to the publication of the Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Eleventh Annual Report of that Station, namely, that for the year 1898.

The accompanying report of the Treasurer gives the details of receipts and expenditures. We refer you to the report of the Director and his associates for a statement of the work accomplished during the past year. We are confident that the funds have been wisely expended and that the work accomplished is such as will result in great benefit to our agricultural and other interests.

Respectfully submitted,

T. S. GOLD,
W. E. SIMONDS,
G. W. FLINT,
Executive Committee.

Report of the Treasurer

FOR THE FISCAL YEAR ENDING JUNE 30, 1898.

The following summary of receipts and expenditures, made out in accordance with the form recommended by the United States Department of Agriculture, includes, first, the Government appropriation of $7,500, and, secondly, the annual appropriation of $1,800 made by the State of Connecticut, together with various supplemental receipts. These accounts have been duly audited according to law, as is shown by the Auditors' certificates, copies of which are appended.

GOVERNMENT APPROPRIATION — RECEIPTS AND EXPENDITURES.

RECEIPTS.

United States Treasury,	$7,500 00

EXPENDITURES.

Salaries,	$3,918 36
Labor,	1,246 50
Publications,	27 23
Postage and stationery,	262 95
Freight and express,	68 43
Heat, light, and water,	282 10
Chemical supplies,	140 05
Seeds, plants, and sundry supplies,	287 71
Fertilizers,	130 83
Feeding stuffs,	266 42
Library,	45 52
Tools, implements, and machinery,	21 45
Furniture and fixtures,	127 50
Scientific apparatus,	255 94
Live stock,	16 90
Traveling expenses,	360 27
Contingent expenses,	10 00
Building and repairs,	31 84
Total,	$7,500 00

STATE APPROPRIATION AND SUPPLEMENTAL RECEIPTS — RECEIPTS AND EXPENDITURES.

RECEIPTS.

State of Connecticut,	$1,800 00
Miscellaneous receipts,	400 00
Total,	$2,200 00

EXPENDITURES.

Salaries,	$878 58
Labor,	603 11
Postage and stationery,	30 19
Freight and express,	17 15
Heat, light, and water, including electric power,	107 20
Chemical supplies,	10 45
Bacteriological investigations,	300 00
Seeds, plants, and sundry supplies,	111 73
Tools, implements, and machinery,	50
Furniture and fixtures,	62
Scientific apparatus,	60 13
Live stock,	2 50
Traveling expenses,	11 04
Contingent expenses,	2 00
Building and repairs,	64 80
Total,	$2,200 00

HENRY C. MILES, *Treasurer.*

AUDITORS' CERTIFICATES.

MILFORD, CONN., January 26, 1899.

This certifies that we have examined the accounts of Henry C. Miles, Treasurer of Storrs Agricultural Experiment Station, for the fiscal year ending September 30, 1898, for the investigation of food economy, compared them with the vouchers and found them correct. The amount of the annual appropriation received and expended was eighteen hundred dollars.

FRANKLIN B. NOYES,
D. WARD NORTHROP,
Auditors of Public Accounts.

This certifies that we have this day examined the accounts of Henry C. Miles, Treasurer of the Storrs College Experiment Station for the fiscal year ending June 30, 1898, and have compared said accounts with the vouchers and found the same to be correct, showing receipts and expenditures both amounting to the equal sum of $7,900, and no balance remaining on hand.

THEODORE S. GOLD,
W. E. SIMONDS,
Auditors of Storrs College.

Hartford, August 19, 1898.

Report of the Director for the Year 1898.

The work of the Station during the past year has been along the lines followed for several previous years. The principal subjects of inquiry have been the effects of fertilizers upon the growth and composition of plants, dairy bacteriology, the feeding of cows and sheep, and the food and nutrition of man.

EXPERIMENTS UPON THE EFFECTS OF FERTILIZERS ON THE PROPORTION OF NITROGEN IN PLANTS, AND UPON THE AMOUNT OF THE CROPS PRODUCED.

These experiments have been made with grasses of different kinds, oats, corn, potatoes, cow peas, and soy beans, grown in field and garden plots, and in pots. The experiments in field and garden plots have been in progress for a number of years, and results have been published in previous Reports of the Station. In the field experiments during the early years, attention was given to the amounts and composition of the crops provided with different fertilizers. For two or three years past more especial attention has been devoted to the effects of mineral and nitrogenous fertilizers upon the proportions of nitrogen in the plants grown, with their use both in field and garden plots. Pot experiments for the study of the same question have been lately undertaken.

DAIRY BACTERIOLOGY — BOVINE TUBERCULOSIS.

The inquiries in these lines have had reference to two general topics; bovine tuberculosis, and the effects of bacteria in the handling of milk and the making of butter and cheese. The experimental work of the past year has been carried on by Mr. Esten, who has for several years been the assistant of Prof. Conn. The most important contribution, however, has been made by Prof. Conn, who has improved a year's stay in Europe to visit universities, bacteriological laboratories, hygienic institutes, experiment stations, and dairying establishments in England, Holland, Denmark, Germany, Switzerland,

and Italy. The results of Prof. Conn's observations on bovine tuberculosis are epitomized in Bulletin No. 19 of the Station, on "The Present Condition of Bovine Tuberculosis in Europe." They are given in more detail in an article on the same subject in the present Report. Another article by Prof. Conn gives the results of his observations on the practical applications of bacteriology in European dairying, especially in the handling of milk and the making of butter and cheese.

Much more attention has been given to these subjects by bacteriologists and practical dairymen in Europe than in the United States. The results of this foreign experience as collated by a specialist, with such unusual opportunity for personal observation, can hardly fail to be of particular interest to farmers in Connecticut and elsewhere. A large amount of space is accordingly given to them in the present Report.

The experiments with tuberculous cows at the Station, of which an account was given in the Report for 1897, have been continued. Some of the more important and interesting results of these investigations are given in the present Report. These experiments will be continued during the coming year.

The experiments on the bacteria of milk and cream and their influence on butter-making, which have been carried on by Prof. Conn and his assistants for several years, and have been described in the Reports of the Station, are being continued.

FEEDING OF COWS AND SHEEP.

The studies of the rations fed to milch cows, and their effects upon milk production, which have been carried out for several years past with the Station herd and with private herds in different parts of the State, have been continued, but on a plan somewhat different from that of previous years. The length of the individual experiments has been increased to three months. During the first half of this period the rations found in previous use were continued, and during the last half a new ration, suggested by the Station, was adopted. These later rations were determined according to the milk-producing capacities of the cows rather than their avoirdupois weights, for reasons described in detail in the Report of last year. The experiments of the past year were not decisive. Experience is necessary for the working out of the details of the experimental method, and the experiments are being continued.

Experiments on the fattening of sheep for the market have been made with the co-operation of Mr. Charles E. Lyman of Middlefield, one of the largest and most successful sheep-feeders in New England.

Digestion experiments with sheep have been continued. These are tests of the digestibility of different feeding stuffs, more especially those used in the feeding experiments with milch cows. Experience has shown that sheep digest nearly the same proportions of these materials as cows, and as experiments are more easily made with sheep they are used for the purpose.

THE FOOD AND NUTRITION OF MAN.

The Act of Congress providing appropriations for experiment stations in the different States makes provision for the study of the economy of the food and the laws of the nutrition of man. Congress also provides a special appropriation of $15,000 per annum for inquiries in these directions. The responsibility of their execution rests in the Secretary of Agriculture, who has appointed the director of this Station as special agent of the Department of Agriculture in charge of nutrition investigations. The Legislature of Connecticut makes an appropriation of $1,800 per annum for studies of food economy, and of the bacteriology of milk. The investigations by the Station on the food and nutrition of man are accordingly carried out in co-operation with the United States Department of Agriculture, and thus form a part of an extended system of inquiries, which are under the immediate supervision of the director, and have been and are being prosecuted in experiment stations, colleges, universities, and in co-operation with benevolent organizations in Maine, Massachusetts, New York, New Jersey, Pennsylvania, Virginia, Tennessee, Alabama, Missouri, Indiana, Illinois, Minnesota, North Dakota, California, and New Mexico.

The topics that have received especial attention are the composition of food materials, the kinds and amounts of food consumed by individuals, families, boarding-houses and institutions, the digestibility of food materials, and the fundamental laws of nutrition. The most important work of the Station is found in the experiments with man in the respiration calorimeter. Arrangements are being made for similar experiments with domestic animals. The object of these experiments is to gain more definite knowledge than we now have

of the action of the fundamental laws of the conservation of matter and the conservation of energy in the living organism. The research is abstract, time-consuming, and costly, but the results already obtained are highly encouraging. It is my belief that no work which the Station has attempted is producing or will produce results so valuable, whether viewed from the standpoint of pure science, or that of practical utility, as those of this class.

ANALYSES OF FOODS, FEEDING STUFFS, ETC.

In connection with the experimental inquiries above named, a large number of chemical analyses are required. These include analyses of the crops grown in the fertilizer tests, of the feeding stuffs used in feeding experiments with cows and sheep, of the foods used in experiments with man, and of the excretory products in the experiments with animals and man. In addition to the regular analytical work, inquiries have been made leading toward the improvement of the present methods of analysis.

METEOROLOGICAL OBSERVATIONS.

The usual observations of temperature, barometric pressure, wind velocity, humidity and precipitation have been made at Storrs. In addition, records of rainfall during the growing season have been made in other places in the State by farmers who have co-operated with the Station.

W. O. Atwater, *Director.*

THE PRESENT ATTITUDE OF EUROPEAN SCIENCE TOWARD TUBERCULOSIS IN CATTLE.

BY H. W. CONN.

When the subject of tuberculosis was before the Connecticut Legislature two years ago, it was urged by representatives of the Storrs Experiment Station that more information as to the actual condition of facts was needed. The Legislature did not see fit to make any appropriation toward obtaining such information. The Station was thoroughly convinced of its necessity, however, and during the last year, partly through aid from the Experiment Station and partly through the generosity of Wesleyan University, I have been enabled to visit many of the chief centers in Europe, where the matter of bovine tuberculosis has been a subject of special investigation. The opportunity has been used as far as possible to obtain information as to the attitude of European scientists toward problems which concern tuberculosis among cattle, as well as to inquire into the lines of experimenting which are now going on. The present paper is designed to put into the hands of Connecticut farmers the most recent information to be had upon this important subject. While the statements given apply primarily to the problem as it exists in Europe, they interest our own communities as well.

In such a discussion it is not always easy to distinguish fact from theory. It is, however, the failure to distinguish demonstrated fact from mere inferences that has given rise to much of the confusion and disagreement among those who have discussed this subject. It will be my endeavor, therefore, in this paper to make no statements as definite unless they are so well attested by facts that they may be regarded as parts of scientific demonstrations. Where opinions differ in regard to important points, the differences of opinion will be noted. Of course it is sometimes a matter of personal opinion as to whether any particular conclusion is demonstrated or still hypothetical, but it will be my aim, so far as possible, to make as definite statements only such conclusions as are acknowledged among scientific men as being proved.

The agitation over the tuberculosis question is upon a rather different footing in Europe from what it is in the United States. In this country the agitation very largely interests the people. In Europe the interest is thus far chiefly confined to the scientist. Our agricultural communities are, as a rule, better informed upon matters relating to agriculture than those of Europe. The large amount of scientific literature which is being put into the hands of our farmers by our agricultural journals and government publications make our farmers much better informed than the farmers of European countries. Hence it is that while in this country the farmer feels that he is especially interested in the tuberculosis problem, and that this is a subject that he must help settle, the farmer in Europe, as a rule, takes less interest in the matter, and looks upon it as something that the government must settle for him. The European scientists, therefore, who have studied into the matter are, as a rule, more interested in it than our own, while the public at large knows and cares less of the matter. Scientific men are leaders in legislation in Europe to a greater extent than they are in the United States, and, as a result, less mistakes have been made in legislation in Europe than in this country.

The subject before us will be considered under three heads: I. The present condition of tuberculosis among cattle. II. The battle waged against tuberculosis on the part of the agriculturist. III. Practical conclusions.

I. THE PRESENT CONDITION OF TUBERCULOSIS AMONG CATTLE.

A. CAUSE.

The cause of tuberculosis is to-day very well known, and so widely distributed is the knowledge with regard to it that little need be said upon the subject. The *tuberculosis bacillus* was discovered about fifteen years ago by Prof. Koch, and all of the investigations that have been carried on since that time have only served to confirm the conclusion that tuberculosis is in all cases produced by this particular bacillus. This tuberculosis bacillus is a small plant, which has the power to live as a parasite in the bodies of a number of mammals. If it finds entrance into the body it can feed itself upon the tissues of the animal, it can grow and multiply and continue to live under these conditions for a long time. As a result of its growth it produces certain chemical bodies which are very

poisonous and are probably identical with *tuberculin.* These poisons directly affect the tissues of the animals within which the bacillus is growing, causing various pathological growths which characterize the disease. The tubercules so characteristic of this disease are simply pathological growths in the animal, stimulated by the poisons excreted by this little microorganism. The tubercle bacillus is capable of living as a parasite in quite a large number of warm-blooded animals. Those with which we are the most interested are, of course, man and cattle, but in addition to these we find that the bacillus can live as a parasite in horses, birds, rats and mice, pigs, goats, sheep, cats, dogs, and, indeed, other animals. The last four take it rarely. The only ones with which the agriculturist is especially interested are cattle and swine. The presence of the bacillus in other animals is too rare to make it a factor of any importance in agriculture.

The question whether the bacillus which produces the disease in man is identical with that found in cattle has always been one of very great interest and manifestly of very great importance. Upon the affirmative settlement of this question rests the possibility of the transference of the disease from animals to man and from man to animals. It has been very generally believed by scientists from the very first that the species of bacillus found in man and cattle are the same. There appears to be no difference in the bacillus as found in these two animals, when it is studied with the best microscopical apparatus. It has been shown by demonstration that the tuberculous material from man may produce the tuberculosis disease in cattle, and there have been many instances that point to the conclusion that the disease has been transmitted from cattle to man. If the disease can thus be carried from one to the other, there can be no question that the bacillus is the same in both animals. But there are still some facts which forbid us to give a positive answer to the question, and there is as yet no absolutely uniform opinion upon the subject. It has been learned as the result of recent experiments that, although there may be but one species of tubercle bacilli, there are a number of varieties more or less distinct and of different virulence. Some of these varieties appear to have a very much more decided power of producing the disease than others. Some of them inoculated into an animal will produce a virulent case of the disease, while other varieties under similar circumstances produce only a mild type. Recognizing, then,

that there do exist varieties of the tubercle bacillus, the question as to the identity of the bovine and human germs assumes a new aspect. May it not be that while the species is the same in both cases, the variety which is found in the one animal is slightly different from that found in the other, so that a type which produces a violent case of tuberculosis among animals might be one which would have very little effect upon man, and *vice versa*? It is manifest that this question will very materially affect the whole problem of the transference of the disease from man to animals. This question we will refer to again, later.

B. PREVALENCE OF TUBERCULOSIS AMONG CATTLE.

When the attempt is made to determine the prevalence of tuberculosis among cattle we meet with the very greatest difficulty. Nothing would seem to be easier at first thought than to determine to what extent our herds are infested with a disease so well known as this, but the more the attempt is made to obtain statistics, the more do we learn our ignorance upon the matter. The statistics vary so widely, and those taken at one place are so incomparable with those taken from another locality, that the whole question of the prevalence of tuberculosis is one with regard to which there is a vast amount of uncertainty.

There are two methods by which the prevalence of tuberculosis among cattle can be determined. The first is by the examination of animals slaughtered in slaughter-houses, and this is the only one which has been complete enough to give any definite conclusion. In several countries, official inspectors examine the animals slaughtered in slaughter-houses and make reports as to those in which evidence of tuberculosis is found, and these reports, as they accumulate year after year, should in time give a tolerable notion as to the amount of tuberculosis. But even this simple method of determining is subject to the widest amount of individual variations which are not connected with the actual amount of the disease. The results are influenced firstly by the skill of the inspector who makes the observations. An inspector with little experience may make many mistakes in diagnosing tuberculosis, and his results will be unreliable. The results are affected secondly by the care with which the inspection is made. Frequently the tuberculosis in a slaughtered animal may be developed to such

a slight extent that only a very minute lymphatic gland may be infested with the disease. In some cases a swollen gland no larger than a pea, and sometimes even smaller, will be the only evidence of the presence of tuberculosis. Now, in such cases it is, of course, very evident that an inspector who has many hundreds of animals to examine in a day and does his work somewhat hurriedly will overlook many instances of such incipient tuberculosis, while a second inspector, who has more time and a smaller amount of work to do, will discover them. The care that is given to the inspection, then, will affect the statistics very materially, and the figures that come from one slaughter house may therefore be absolutely incommensurate with those that come from the second. The results are affected, thirdly, by the personal inclination of the inspector, a factor that always enters largely into the statistics. One inspector desires to prove the wide prevalence of the disease and examines the carcasses much more carefully than the second, who is either indifferent, or desirous to reach the conclusion that tuberculosis is not very prevalent. The former will hunt carefully for all cases where even a small gland may be infested; the latter will overlook them. The result is that it is almost impossible to compare the statistics given at one slaughter house with those obtained at a second.

A second series of facts that very much influences these statistics is connected with the age of cattle that are brought to the slaughter-house. It is a well demonstrated fact that in Europe old cows are very commonly tuberculous, some veterinarians going so far as to say practically *always* affected with tuberculosis, while young animals are much more rarely affected. Now, if one slaughter-house chances to have only old cows brought to it for slaughter, while a second is concerned chiefly with younger animals, the statistics obtained by the one will be radically different from the other's, and inasmuch as no record will be commonly made of the age of the animals slaughtered, the statistics will give very erroneous conclusions. For these reasons, then, we see that statistics, even derived from such a clear method as examinations of carcasses, must be looked upon with suspicion.

A second method of determining the presence of tuberculosis is by the use of tuberculin. As is well known by every farmer, the inoculation of an animal with tuberculin will detect very accurately the presence of this disease, and will show its presence in living animals in many cases where clinical symp-

toms are absent. As would be expected, the amount of tuberculosis detected by this means is in excess of that indicated by the slaughter-house records. Tuberculin, as we shall see presently, detects incipient cases, and many a case that would be entirely overlooked by the most careful inspector of flesh. Moreover, it must be remembered that in no country has there been anything like a general inoculation of the animals from which could be obtained average results. Only such herds are generally tested with tuberculin as are somewhat suspicious. The results obtained from such a herd would be largely in excess of those which would be obtained if tuberculin were used upon all animals indiscriminately.

Considering, then, the uncertainty of the methods of getting statistics, it is not surprising to find that the conclusions as to the prevalence of tuberculosis among cattle are at wide variance with each other. The estimates run all the way from zero in some herds to one hundred per cent. in others, and the attempt to draw any average from such widely varying results is extremely fallacious and misleading. Nevertheless, taking together all of the facts derived from all sources, it is possible at all events to get some idea as to the relative amount of tuberculosis in different places and under different conditions.

It is found that the amount of tuberculosis among cattle varies with the climate. In the southern countries of Europe, like Italy, Spain, Switzerland, the amount of tuberculosis among cattle appears to be comparatively small, although this may be partly because it is less studied. The same is true on the whole continent of Africa, and to a considerable extent, also, with the cattle in the western plains of the United States. On the other hand, the amount of tuberculosis among the northern countries of Europe, Germany, Denmark, Belgium, Great Britain, is relatively large. Statistics are apparently showing to-day that the amount among our own herds in the eastern section of the United States is also large, possibly approaching in its extent that of some of the countries in Europe.

The variation in the amount of tuberculosis is to a certain extent parallel with the amount of outdoor life of the animals. In the southern countries of Europe, in Africa, and in our western territories, the animals are kept largely out of doors, and so long as they do not go into the stall and remain housed they are only slightly liable to this disease. In the countries, however, where the animals are kept indoors a large propor-

tion of the time, bovine tuberculosis is much more prevalent, and the amount of tuberculosis is roughly parallel to the extent of indoor life. Where the cattle are kept housed all the time, the amount of the disease is very large. There are two or three factors which probably explain this fact. In the first place, animals living indoors do not have as much air, and the activity of their lungs is impaired thereby. They are therefore more subject to an attack of the disease than animals living outdoors, where air has more easy access to the lungs and where vigorous exercise in the open fields keeps the lungs in a more active condition. Secondly, a very prominent factor is, doubtless, the fact that the tubercle bacillus has a very much more easy chance of access to animals in the stall than out of doors. Inside of the barn the cattle come in close contact with each other, and there is every possible means by which the germ can pass from one animal to the other. Out of doors there is not this close contact. Thirdly, it is a well known fact that the sunlight quickly destroys tubercle bacillus together with all other bacteria, and, therefore, if the animals live in the fields the tuberculosis bacilli which are excreted from them in any way are very rapidly killed by the rays of sunlight, so that after a comparatively few hours they are harmless. In the dark stable, however, they may remain alive and active for months. These three factors together very largely explain the greater prevalence of the disease in housed animals. It must not, however, be understood that tuberculosis is absent from animals that live out in the fields. It occurs occasionally in animals who never enter the barn, but the amount of disease among animals living in the free air is very decidedly less than in those living indoors.

We find, furthermore, that the amount of tuberculosis varies with the breed of the animal. There is no general agreement as to what breeds of animals suffer most. Some claim that Jerseys, Shorthorns, and Ayrshires are especially susceptible, but it is doubtful whether this is true. In general, the animals of high pedigree stock are more subject to the disease than ordinary cattle. The reason for this is probably not especially connected with the breed, but rather with the conditions under which they are kept. These valuable animals are usually great milkers, and their general vitality is somewhat lowered by the strain upon the animal to produce milk. This lowering of the vitality by a great production of milk renders the animal somewhat more liable to attack than

is the animal that is not thus weakened. It is probable, also, that other factors connected with the care of high bred stock, their being more generally housed, being kept warmer, tend to weaken the vitality of the animal so that the greater prevalence of tuberculosis in high bred stock is probably explained by conditions surrounding such stock rather than by anything peculiar in breed itself.

It is found, further, that the amount of tuberculosis varies with the sex of the individual. Apparently, female cattle are somewhat more liable to the disease than are male cattle. The difference, however, is quite slight.

It is found that the amount of tuberculosis varies with the size of the herd which any individual farmer produces. This is a significant fact, and at first somewhat surprising. If a farmer has a large herd of animals, one or two hundred or more, it is very likely to be infested, while the smaller herd of his neighbor may be free from it. Large herds show, also, a considerably greater per cent. of the disease than small herds. It is not difficult to understand that this should be so. An owner of a large herd is constantly buying new animals and thus increasing the chance of infection. In large herds, too, the chances of contamination of one animal by another are decidedly greater than in small herds. If a farmer keeps only a few animals he is less likely to buy infected creatures, and hence the chance of infection is greatly reduced. At all events this is found to be almost universally the case. Tuberculosis is more prevalent among large herds.

Taking all these things together, it is evident that any estimates as to the amount of tuberculosis present in our herds is almost valueless. And yet the figures that are given may be, at all events, interesting, and will certainly serve to indicate a prevalence of tuberculosis rather greater than has been generally believed. Taking the statistics which are derived from slaughter houses as the most reliable, we find that apparently the amount of tuberculosis among the herds in Europe varies from a minimum which cannot be given to as high as over fifty per cent. in all animals over one year of age. In the city of Leipzig, where the best records are kept, the amount is about thirty-three per cent. It must, of course, be understood, in speaking of these figures, that in these cases we have actual tuberculosis as discovered by post mortem examination. We must remember, too, that advanced cases of tuberculosis do not reach the slaughter-house, the owner knowing that the

bodies would not pass inspection. We must remember, lastly, that many a case of tuberculosis, if it be a very slight one, will escape observation entirely. Remembering these facts, and considering that the slaughter-house records give us a prevalence of tuberculosis sometimes as high as fifty per cent., or more, it is thoroughly demonstrated that the amount of tuberculosis among cattle in Europe is really very great. In the most recently reported statistics from the slaughter houses in Kiel, a city of North Germany, it is stated that sixty-six per cent. of the cows imported from Denmark have been found to be tuberculous. It is probably impossible to give any statistics of American cattle that would be comparable to these, chiefly because we have no complete slaughter-house records. Animals are slaughtered in the United States in so many private slaughter-houses, and official inspection is such a rarity, that we have no slaughter-house statistics that can be compared with these in Europe.

If we take the results of tuberculin inoculation we shall find that they are decidedly higher than those derived from slaughter-houses. In some of the northern countries the conclusion has been reached by those who have most studied the matter that the amount of tuberculosis is over fifty per cent. of all the animals in the land. Many small herds, especially those which have been all bred on one farm without purchase, will be entirely free. Larger herds, on the other hand, will have seventy and eighty per cent., and many large farms can be found without a single sound animal. But, taken altogether, it is admitted without any dispute that the amount of the disease in some northern countries is very nearly fifty per cent. This means, of course, that about one-half of the animals are afflicted with tuberculosis.

In general, then, as to the prevalence of tuberculosis, we may say that it varies very widely, running from zero up as high as fifty per cent. In some countries it may be small, but in none of the thickly-settled countries is the presence much less than ten per cent., and in most of them very much greater than this.

C. THE INCREASE OF THE DISEASE AMONG CATTLE.

A very vital question connected with the whole subject is whether tuberculosis among our cattle is on the increase at the present time. There is undoubtedly a very widespread

belief that such is the case. Certain it is that the statistics as they are being collected in the last few years are tending to show that tuberculosis is not only on the increase, but on the very rapid increase. The amount of tuberculosis as it is determined by the sources of evidence already pointed out is becoming larger and larger each year.

It is, however, difficult, if not impossible, to answer positively the question as to what rate tuberculosis is increasing. The uncertainty of the sources of evidence which have just been pointed out apply with equal or even greater force when we attempt to answer this question. To such an extent is this true that statistical evidence upon this question is of very little value and, indeed, almost worthless. Of course it is evident at the outset that no facts derived from the tuberculin test can give us any idea of the increase of the disease, inasmuch as this test is so new that it is only just beginning to be used, and, since the tuberculin test will discover many cases that have hitherto entirely escaped observation, the data derived from this source give no means of comparison with the past.

It might be supposed, however, that the data derived from slaughter-house statistics would be more significant, because inspection of the carcasses of slaughtered animals has been taken in some countries for many years. If these statistics are compared with those of earlier years, the results are to show a surprising and startling increase in the disease. Twenty-five years ago the amount of tuberculosis reported from such inspection was only three to five per cent. To-day it is ten to fifty per cent., and more often approaching the higher than the lower figures. This increase of eight to ten fold in the course of twenty-five years is, of course, very suggestive, at all events. But even here we must recognize that the value of these figures is extremely questionable. We know perfectly well that at the present time our veterinarians are making the inspection with a great deal more care than in earlier years. They have learned to recognize incipient cases of the disease more readily. They note at the present time cases where a single swollen tuberculous gland is found, and in earlier years such instances would never have been noted at all. The great interest that has been attached to the disease has, in short, made the inspectors of cattle so much alert in discovering its presence in carcasses that it is doubtful whether the figures obtained to-day can be compared at all with those obtained twenty-five years ago under conditions in which the veterinarians' atten-

tion was only incidentally turned to tuberculosis. It may, however, be worth while, at all events, to give a few figures illustrating these statistics.

Amount of tuberculosis as shown by slaughter-house records:

Bavaria.	Berlin.	Saxony.	Leipzig.
1877....1.62%	1883....2.86%	1888.... 4.90%	1888....11.1%
1888....2.7%	1885....2.10%	1890....15.7%	1889....14.9%
1895....5.%	1895...15.45%	1895....27.48%	1890....22.3%
			1891....26.7%
			1895....33.3%

The figures here given show certainly an extraordinary increase, and the last three years shows that the figures are still growing larger. Because of the reasons mentioned, statistics from slaughter-houses are only of value when they come from the same place and have been continued in the same locality for a period of years. It is probably impossible to compare with any accuracy figures taken from different localities and, moreover, even in the same locality, the figures are not comparable year after year unless the same inspector has been engaged in the duty of inspection. The personal equation is so great, the desire of some inspectors to find every case of the disease, and of others to find as few as possible, so interferes with the value of the statistics that the comparison of different localities and of different years in the same locality is open to very serious question. The figures given above for Leipzig are the most valuable, since they have extended over many years under the same management. The results in successive years are, therefore, probably more properly to be compared with each other than in most cases. But even here the personal factor and the increased attention must enter into the statistics. But the increase from 11.1 per cent. to 33.3 per cent. in seven years is startling. It is impossible to believe that these uniform results can be explained except by an actual increase in the amount of the disease. After allowing all weight to the personal equation we cannot avoid the conclusion that the statistics which are obtained from slaughter-houses and the absolutely uniform increase in the percentage of tuberculosis, as given by official reports, as well as the large amount of tuberculosis that is found yearly as the tuberculin test is extended, tell only too clearly that tuberculosis is on the increase in Europe. Most scientists are inclined to think that it is not only increasing, but increasing very rapidly. Certain

it is that the figures which have been shown above, if they indicate anything, indicate that the increase in the disease is not a slow one, and, while we recognize the uncertainty of the statistics, we must admit that this disease is beyond much question increasing in European herds with considerable rapidity.

In the United States there are practically no data from which any inferences can be drawn. The use of tuberculin is too new and has not been extended sufficiently to give any conclusions from this source, and official inspection of slaughtered animals has not been carried to an extent in this country to make it possible to draw any conclusions as to the increase of the disease here. There is probably little doubt that its course is the same as in foreign countries, and there is a general belief that it is increasing, but the question cannot be answered positively.

D. MEANS OF DISTRIBUTION OF TUBERCULOSIS.

Of all the topics connected with the subject of tuberculosis among animals and man, there is none of more importance from every standpoint than that of the method by which it is distributed from individual to individual. If we could learn this accurately we should be far along toward the solution of the problem of the weeding out of the disease, both among cattle and in the human race. It is a subject over which there has been a very large amount of study and thought and, as we shall see, a subject over which at the present time there is a very wide difference of opinion. Certain methods of distribution are well known and generally accepted, but upon nearly every point in connection with the subject there is some difference of opinion. In our consideration of this subject we will divide it into three heads, as follows: (a) Transmission from animal to animal. (b) Transmission from man to animal. (c) Transmission from animal to man.

(*a*) TRANSMISSION OF TUBERCULOSIS FROM ANIMAL TO ANIMAL.

The first point to demand attention in this connection is the question as to whether the disease is congenital, that is, whether it is carried from the parent to the offspring. While there has been in the past a great deal of dispute upon this matter, and while opinion has been greatly changed in the last fifteen years, it may be stated that finally there has been reached an absolute consensus of opinion. There is no longer

a doubt that the transmission of tuberculosis from the animal to the offspring, while it is of rare occurrence, occasionally does occur. This has been proved in the case of cattle by the discovery, in the first place, of the disease in new-born calves, and, secondly, by the discovery of the disease even in the embryo calf before birth. It is of course easy to understand how the tuberculosis germs which are present in the mother may find entrance through the uterus into the embryo before birth, and if so, congenital tuberculosis is certainly a possibility. The discovery of the disease well advanced in new-born animals and the discovery of well attested cases of the disease in the embryo settles the matter beyond question, so that one can no longer doubt that the disease may be congenital.

But, while this is true, the cases of congenital tuberculosis are so rare that they may be almost neglected in consideration of methods for preventing the distribution of the disease. The vast majority of calves born from tuberculous mothers are healthy and show no signs of the disease at birth. Whether they are more subject to subsequent infection than are the calves of healthy animals is still, perhaps, uncertain. It is a general belief that in the human race the children of tuberculous parents are more likely to take the disease than children of other parents. This is at all events a possibility, and perhaps we may say a probability, among animals as well as man. The fact that an animal has yielded to the disease would indicate that it has less resisting power than another animal that has not thus succumbed. It would be natural to suppose that this resisting power, being a result of the general vitality of the animal, might be transmitted to the offspring. Hence it would follow that offspring from tuberculous animals would be more likely to yield to the infection than the offspring of non-tuberculous cattle. But this is not yet demonstrated.

Tuberculosis is now well known to be a contagious disease, and that it in some way passes from individual to individual is beyond doubt. That it extends through a herd of cattle from one infected individual to others appears also to be well attested by many instances. Nearly every farmer will recall cases where the introduction of a single tuberculous animal into a herd has been the cause of the spread of the disease through the herd until a considerable portion of the animals have been infected. It is certainly a general belief among practical agriculturists, and among scientists as well, that this

is the common means of distribution through our herds of cattle. In previous years there was no tuberculosis among cattle in Japan, but a few years ago it was brought to the country by certain imported animals, and has subsequently extended quite widely, largely, it is true, among the imported cattle. In Denmark it was first introduced by cattle from Schleswig, and has since spread widely. It is a belief, also, that the same was the history in the United States, that the tuberculosis in our cattle is to be traced to the importation of certain animals from the Old World who had the disease.

When the question is raised as to exactly how the disease is carried from one animal to another, the answer is not so easily given. The disease can only be transmitted from one individual to the second when the tubercle bacillus itself finds an exit from the diseased animal and finds some entrance into the body of a healthy animal. The common channels of entrance are the mouth and nose, although it also may gain access to the body through the sexual organs, through the mammary glands, and through wounds. The last three methods of infection are of comparatively little importance. To pass from one animal to another the bacilli must of course first find an exit from the infected animal. The most common location of the disease among cattle is in the lungs, although it is present also in a very large amount in the other organs. Cattle, however, do not void sputum from the mouth, and thus sputum, which is regarded as the most common means of the distribution among man, can play little or no part in the distribution among cattle. It is true that the bacilli as they come from the lungs may pass up into the mouth and the nose of the animals, and when there are slight discharges from the nose and mouth, as is not uncommon, these may be means by which the germs are eliminated from the animal. It is quite easy to understand how a cow suffering from tuberculosis in the lungs may thus infect the water in the watering trough from which she drinks, by dipping her nose into the water, and thus allowing some of the germs which are in the nose or mouth to pass into the water. It is easy to understand, then, how a second animal, drinking from the same trough, may get the germs into her own mouth and stomach and thus become infected. While this is a possible method of distribution, we must recognize, however, that among cattle the discharges from the lungs do not, as a rule, pass from the mouth, but are swallowed, and consequently the bacilli will tend to pass into the stomach rather than to pass

out of the mouth. The bacilli that thus pass through the stomach may eventually serve for a secondary infection in the alimentary canal of the animal, or they may pass away in the excrement. The boots of the attendant will now distribute the excrement from stall to stall, and even infect with the bacilli the hay which the cows are to eat. Anyone familiar with the habits of the attendants of cattle will easily see how the disease may be thus distributed by the excrement of infected animals.

A second source of elimination of the bacilli from the lungs has recently been discovered and must not be neglected. It has been shown by recent experimental work that one of the common methods of the distribution of germs is in the small particles of vapor which pass into the air from the mouth or lungs of an individual when coughing. Ordinary breathing has for a long time been known to have no power to distribute bacilli, since they cling to the moistened surface of the mouth and throat; but the most recent experiments have shown that in the case of coughing, minute particles of water are discharged from the mucous membranes of the mouth and throat and are blown into the air, where they float around for a time in the form of an imperceptible mist. They may now be distributed for long distances by the currents of air, even in a closed place, like a cow stall. If the air thus becomes charged with the bacillus-laden drops of moisture, it is perfectly clear that healthy animals, even if some distance away, in the same apartment may breathe these particles of moisture into the lungs and thus obtain infection. The bacilli from all these sources will adhere to the rough surfaces of the cow-stall, and may necessitate frequent disinfection.

Another method by which the animal may convey the bacilli is by actual contact with other animals, especially if the animals bring their noses together or if they cough in each others faces. If they are eating out of the same mass of hay, one may infect the food with the bacilli from its mouth and the other individual swallowing the hay may thus become infected.

That the milk of a tuberculous animal may under certain conditions contain the bacilli is demonstrated beyond question. It is clear that the calves sucking milk from a tuberculous mother may from this source obtain the bacilli, which start an infection in their own bodies. If such milk is carried to a creamery and run through a separator, the skim-milk will contain many of the bacilli. Now, by the ordinary cus-

tom, the farmer who brings his milk to the creamery carries home a lot of skim-milk to feed to his calves and pigs. He never gets his own skim-milk, but that which is running through the separator at the time he is at the creamery. It is evident, therefore, that if there are any tuberculous cows furnishing milk to the creamery, their skim-milk will in time be distributed all over the territory patronizing the creamery. In this way, calves and pigs may acquire the disease. The slime which collects upon the drum of the separator is full of tubercle bacilli. This is frequently fed to pigs, and as a consequence in Northern European countries such swine become very rapidly infested with tuberculosis. The separating creamery becomes thus a prolific means of dissemination of the germs of tuberculosis. To avoid this danger, in some countries the skim-milk is pasteurized (*i. e.*, heated to 170°) before being given to the farmer, and the slime from the machine is burned.

There seems to be, then, little question that there are easily understood means by which the bacilli can pass from an infected animal to healthy animals. At the same time the facility of transmission is not so great as among men who void sputum. This lack of sputum has so impressed bacteriologists that there are some scientists of repute in Europe to-day who regard the transmission of the disease from animal to animal as of comparatively rare occurrence, and some go so far indeed as to claim that the transference of tuberculosis from animal to animal almost *never* occurs. They tell us that if tuberculosis is found in a herd and is distributed through the herd we must look for some other source of distribution than that from animal to animal. They claim that the chances are so slight of the distribution of the disease from one animal to another that this method may be almost neglected. Such a conclusion, although it is held at the present time by several rather prominent bacteriologists, is not, however, generally accepted; and the vast majority of scientists, bacteriologists, veterinarians, and agriculturists are united in regarding the transference of the disease from animal to animal as the chief method of its distribution among cattle.

(*b*) TRANSMISSION OF TUBERCULOSIS FROM MAN TO ANIMAL.

The question as to whether the disease passes from man to animal is one upon which there is the very widest difference of opinion. We have, as just noticed, on the one hand,

a certain number of bacteriologists who claim that this is the common method of the distribution of the disease, and some who even insist that this is practically the only method by which cattle obtain tuberculosis. These bacteriologists point to a number of very significant facts. In the first place, they emphasize the fact that cattle do not void sputum, while, on the other hand, they show the great likelihood that the disease may pass from man to the animal because of this habit of spitting. That the sputum of the consumptive patient contains the bacilli in large quantities has long been demonstrated, and when this is voided in the barn and becomes dry it may pass into the air and be breathed in by the animals, or, if it comes in contact with the hay or even with the floor in the vicinity of the cow stall, it may be taken into the animal with its food. The chance for such distribution is certainly very great, for attendants are certainly not particular in regard to spitting. These bacteriologists further point to significant facts in regard to the relation of the disease in animals and man. They show us that so long as calves come in contact only with their mothers the amount of tuberculosis is very small; that the amount of the disease, however, increases rapidly year after year, and that this increase in the disease is directly proportional to the contact with man. Calves apparently do not, as a rule, take the disease from the animals with which they are associated, but as they are year after year more and more closely associated with man, in milking and in the general care, the amount of tuberculosis increases. They tell, too, that the amount of the disease in a herd is largely proportional to the healthfulness of its attendants. In sanitary institutes, for instance, where the attendants of the cattle are presumably in considerable measure suffering from tuberculosis, the amount of tuberculosis among the cattle is always very great. We are told that there are practically no cases of healthful herds where they are attended by the patients of sanitary institutes. These bacteriologists tell us, further, that the condition of the herd may be always predicted from the condition of the family that has charge of the herd. If the inspector looks first at the people on the farm and finds one or two of them that appear to have traces of tuberculosis he can predict with absolute certainty that he will find the same disease among the cattle. These facts together have led to an assumption that the transference of the disease from man to animals is not only common, but it is the greatest source of the disease among animals.

There is at least one prominent bacteriologist in Europe who goes so far as to say that this is the one source of distribution, and that the disease practically never is found in cattle unless it comes from the attendants.

Such an extreme position is, however, held by very few. While no one will question the possibility that the disease may be carried from man to animal, it is yet impossible to point out any definite instance where the transference has been proved. This, of course, however, proves nothing in itself, because from the very nature of the case it would be impossible to find evidence for such transference, even if it occurred. But many other facts are indicated as showing that the transference from man to animals is not the common method. In the first place, tuberculosis among mankind has been known for many centuries. Apparently the disease among animals is new, or comparatively new, and if the disease is transmitted solely from man to animal we uttely fail to explain how it is that the disease has been apparently increasing so rapidly in recent years, when, as we know, the disease in mankind has been decreasing. This in itself is enough to indicate that there must be some means of distribution other than from man to animal. Moreover, as mentioned above, in Japan the disease was not known among domestic animals until recent years, and in Denmark it is said to have been introduced by imported cattle from Schleswig. Tuberculosis in mankind, however, has been known in these countries for a long time, but it was not until the disease was brought by some infected animals that it began to extend. If these facts are thoroughly attested, of course it follows that we cannot regard man as the chief or even the important source of the disease in animals.

Whether, then, the disease is transmitted from man to animals is at the present time not definitely settled. That it may be transmitted is certain. That it positively is thus transmitted is not as yet demonstrated. That it is the chief method of the distribution of the disease appears to be very doubtful.

In the most recent period there has been a line of investigation undertaken in our own country which apparently indicates that this source of distribution cannot be regarded as a serious one. A series of facts has led Prof. Smith of Harvard to investigate the question as to whether the variety of the tuberculosis bacillus in man and cattle is the same. The experiment consisted briefly in the following. Several examples of tubercle bacillus were obtained, part of them from human in-

dividuals and part of them from cattle. These were kept under identically the same conditions. A number of calves were inoculated with the bacilli from the different sources. The experiments have really only begun, but the result of the first series was very striking. It was found that the calves which were inoculated with the bacilli that had come from cattle became seriously infected with tuberculosis, which was rapidly diffused and developed to a very great extent. They became, in other words, severe cases of tuberculosis. It was found, on the other hand, that the animals that were inoculated with the bacilli which had come from human beings, while they did develop the disease, developed it only in a mild type. There were produced only slight local tubercles, which apparently soon ceased to develop, and the animals suffered practically nothing from them. In one case the disease extended rapidly and produced serious trouble; in the other case the disease was so slight as to become soon ended. These experiments seem to indicate that the variety of tubercle bacillus that is capable of producing the severe type of the disease in man is not capable of producing the severe type of the disease among animals. Of course, if this is a fact, and the facts must be tested by further experiment before they can be accepted as certainly true, it will follow that we cannot look upon human beings as an important means of distribution of the diesase to the animals. While we may recognize such infection as a possibility and perhaps as occurring rarely, it certainly will follow from these facts that the chief sources by which the disease is distributed to the cattle are other than through their attendants.

(*c*) TRANSMISSION OF TUBERCULOSIS FROM ANIMAL TO MAN.

There is no subject connected with tuberculosis of more general interest than the question as to whether the disease is ever or commonly carried from the domestic cattle to mankind. The discovery of the identity of the disease in man and animals has raised this question, and, since the year 1884, when the tubercle bacillus was first discovered, the question as to the transference of the disease from animal to man has been prominently before the public mind, as well as a subject of scientific investigation. During the fifteen years that has elapsed, many modifications of the original opinions have arisen, and the attitude which the scientific world takes toward

this question to-day is quite different from that which it has been at certain periods in the last fifteen years. It is true that at the present time there is not an absolute consensus of of opinion, but differences of opinion are, to a certain extent, disappearing, and at the present time it may be stated that we are approaching somewhat slowly toward a general consensus of belief upon the matter. The statements which will be given in the following paragraphs are as closely as possible in accordance with the general results and the general belief as they are held at the present time.

In the first place, we notice that there is as yet no evidence that the disease is carried from cattle to man by means of the germs which are coughed up from the lungs and exhaled adhering to particles of moisture, as already described, nor is there any evidence that man obtains the disease by breathing the dust which comes from cattle in any form. While we have no such direct evidence, this by no means indicates that such infection may not occur. From the very conditions of things, if such infection did occur it would be practically impossible to prove it, so that we must not regard this negative evidence as of much importance. If the disease is transmitted from animal to animal by the moisture of the breath there would seem to be an equally good chance for its being transported from animal to man.

Transmission by Flesh. Tuberculous Meat.—There has been a large amount of investigation in connection with the possibility and the probability of tuberculosis being carried from animal to man in the flesh of the animal used as food. A very large amount of experiment in this connection has been carried on in the last fifteen years. These experiments have in large degree consisted in the feeding tuberculous flesh to animals which are known to be subject to the disease, and then the noticing whether such consumption of tuberculous flesh produces tuberculosis in the animals thus fed. The result of these experiments has been conclusive enough. While it does not always happen that tuberculosis will follow the eating of tuberculous material by such animals, it has resulted in a sufficient number of cases to show beyond peradventure that this disease may be transmitted by the flesh of animals suffering from the disease.

In spite of these results the studies and investigations of the last few years have been very rapidly but very conclusively

leading to the belief that the danger of distribution of the disease by the flesh in our markets is extremely small, so slight, indeed, as almost to be neglected. In the first place, no actual cases of the disease being transmitted to man by flesh are known. This, however, may be due to the difficulty of getting evidence of such cases, even if they should occur. But the actual danger appears to be slight. A considerable majority of the slaughtered animals, even though suffering from the disease, have the infection localized only in a few glands. In the ordinary cases the infection is almost always either in the abdominal organs or in the lungs or in some of the lymphatic glands. It is only under very exceptional circumstances that the disease is found in the muscles. Now, if the organs of the thorax and the abdomen are removed after slaughter, all of the organs most ordinarily affected are separated, and the flesh which is sold and consumed for food will contain, in the vast majority of cases, no tuberculous lesion. No one holds that the presence of a small tuberculous gland in the abdomen can have any deleterious effect upon the flesh, and if properly slaughtered the flesh of such animals is wholesome. Such flesh may, it is true, become contaminated during the slaughtering and dressing by the use of unclean knives. It is said that the butcher in removing the visceral organs of the abdomen may cut through the tuberculous parts, his knife may thus become smeared with the tubercle bacilli, and in the subsequent cutting up of the animal the flesh itself may become similarly smeared. Of course, a remedy against such infection would be in a more careful use of the knives. But, even supposing the flesh to be thus contaminated, it is only infected upon its surface, and such contamination never affects the interior of the muscle mass. Now, it must be remembered that the flesh of animals is practically always cooked before it is eaten. It is well known that a moderate temperature, 170° (70° C.) for a few moments, will either completely destroy the tubercle bacilli or so lower their vitality that they are no longer injurious. Hence it follows that the cooking which the flesh receives will practically destroy all danger of the disease being transferred by means of it. It is true that in cooking of beef the interior of the mass frequently may not reach a temperature of 170°, but the surface is practically always thus heated, and this secondary contamination from butchers' knives, being wholly superficial, will be entirely remedied by the cooking. As the result of a long series of inquiries the almost universal

conclusion is reached that the flesh of a tuberculous animal under these circumstances offers no danger to mankind.

There are, however, conditions under which the flesh of the animal may be dangerous. In cases of what are known as generalized tuberculosis the bacilli appear to be scattered all through the tissues, or even in the blood, and in these cases they may be found in the masses of the muscles. No one questions that it is dangerous to eat such flesh unless it is thoroughly sterilized by boiling. But if the advanced cases of the disease are excluded by proper inspection, the universal opinion at the present time is that the flesh of tuberculous animals which comes from creatures with only slightly developed disease is perfectly wholesome, presents no danger, and that there is no reason whatsoever for excluding such flesh from our markets. The only problem is as to the feasibility of a proper inspection. In European countries that are under the best control the carcasses of animals slaughtered in the slaughter-houses are not all treated alike. Some are entirely condemned, this class including only such as have advanced cases of generalized tuberculosis. Others are partially condemned, that is, the viscera, or, perhaps only parts of the viscera are condemned, but the flesh is allowed to be used. In other cases, where the disease is perhaps somewhat more extended, the flesh is allowed to be sold in the markets, upon what is known as the "free bench," which simply means that it is sold to the customer as diseased flesh. The customer buys it at his own risk, and knows that he should not eat it unless after thorough cooking. The method which has been adopted somewhat widely in this country, of entirely condemning the carcasses of an animal that shows the slightest trace of tuberculosis, is adopted nowhere in Europe, and is regarded universally as a needless and useless waste.

In short, there are no cases positively known where mankind has acquired the disease by eating flesh, and all of the facts taken together have led to a unanimous opinion that the danger from the flesh of tuberculous animals has been exaggerated in the past, and that there is no reason why, under proper restrictions, the flesh of such animals should not be used for food.

Transmission by Dairy Products. Tuberculous Milk.—When we come to the subject of dairy products, the matter stands somewhat differently. The danger to man from the consumption of milk and products derived from milk is certainly greater than it is in the case of flesh. All of the evidence that

has been collected during the fifteen years' study has constantly pointed toward the existence of such a danger. The reasons which have led to the universal belief that milk may be a source of danger are essentially as follows: In the first place, as we have seen, it has been demonstrated clearly enough that under certain circumstances the tubercle bacilli are found in the milk of tuberculous animals. Exactly at what stage of the disease the milk may become contaminated with the bacilli has been not so easily settled. While a variety of opinions have been held in the past, the practically unanimous opinion at the present time is that the milk does not become contaminated with the bacilli unless either there is generalized tuberculosis, or the udder itself is the seat of the tuberculous infection. If there is a tubercle in the milk gland, then the milk becomes contaminated. Those who have believed that the milk may become infected, even in animals not suffering from udder disease, have probably either been dealing with cases of generalized tuberculosis in its advanced stages, and here it is also recognized that the milk may become infected, or they have probably had a case of udder disease so slightly advanced as to be not visible externally nor even with the post mortem examination usually given. If now the milk of tuberculous animals may thus contain the tubercle bacilli there appears to be no reason for doubting that the consumption of such milk may produce the disease. To this conclusion innumerable experiments have attested.

The experiments which have been devised for determining the infectiousness of milk have been quite varied. Most of them have consisted of inoculating the milk into the abdomen of susceptible animals, the guinea pig being the animal commonly used, simply because the guinea pig has shown itself to be very susceptible to the disease. Inoculations have been made in other animals, however, as well, such as pigs, rabbits, calves, and others. In other cases, however, the experiments have been made by *feeding* the milk to the animals in question, instead of inoculating them, on the manifest ground that abdominal inoculation is entirely different from consuming milk as food. These experiments have all given the same result, namely, that both the abdominal inoculation and the feeding of such milk to experimental animals is very likely, though not sure, to produce cases of disease. Hundreds and hundreds of positive results have been obtained where perfectly healthy animals, either being inoculated with or fed upon milk from

tuberculous animals, acquired, in the course of a few weeks, plain infection of tuberculosis, while other control animals under the same conditions and fed upon sterilized milk have failed to develop the disease.

The conclusion that milk is thus a possible source of infection is not confined simply to experimental evidence upon animals. Various facts in connection with the disease in man point in the same direction. Many cases have been instanced where persons have developed tuberculosis under circumstances which point strongly to milk as a source. One well known example of this sort may serve as illustration. A boarding school in the city of Paris had fourteen girls, nine of whom were in the course of a few months taken with tuberculosis. An investigation showed that they had all been using milk from one cow, and that that cow was markedly tuberculous. The inference was that the milk of the animal had given rise to the disease in the girls. This is only one instance of which many others are known. Of course it must be recognized that such instances are not proofs, for it is possible that there was some other source of infection than milk. In all similar instances of human beings deriving tuberculosis from milk there is always a little lacking to a complete demonstration. While the probabilities have always been that milk is the source of trouble, the matter is not accurately demonstrated, because of the impossibility of getting demonstrations in regard to so obscure a subject. There has been one recently reported instance which is somewhat closer to a demonstration. It is in the case of a man who had some tattooing performed on his arm and used milk for the purpose. After the tattooing there developed on the arm certain tuberculous swellings, which were plainly traced directly to the operation of tattooing. It was found that the animal from which the milk had been obtained was tuberculous, and the conclusion that this case of skin tuberculosis came from the milk is unquestionable.

It is not necessary to dwell upon this side of the question longer, because the possibility of danger from the consumption of milk is too thoroughly recognized to require extended discussion. It is the universal opinion in Europe and in this country, of those who have looked into the matter, that there is a danger to mankind in the use of tuberculous milk. The question, however, of more importance, and the one in regard to which there has been recently a change in public opinion, is as to the *extent* of this danger. It is possible that man obtains

tuberculosis from milk. Is this a common event, or is it one of extreme rarity? That the danger is greater than the danger from the use of meat is clear enough from the fact that meat is so universally cooked and milk, at least in some countries, so generally consumed without cooking. But this does not tell us that the danger is very great. After careful study of the problem for many years there appears to be at the present time, in the minds of the scientists, an undoubted tendency to regard the danger as very much less than has been supposed. Indeed, so true is this that many of those who have studied the matter carefully are inclined to think the danger is almost nothing, and while it is not to be neglected, it is a danger which is so slight that it does not deserve anything like the amount of attention that has been given to it. The reasons for this conclusion, which is, of course, a satisfactory one, both for the public in general and to the agricultural community, are in general as follows: First, as already indicated, the milk becomes contaminated only in the case of advanced tuberculosis, or in the case of localized udder disease. The cases of advanced tuberculosis will very rarely furnish any milk for the public milk supply, these animals being almost universally excluded from the milk-producing herd. The cases of udder tuberculosis are also rare. According to the best knowledge that we have, probably less than one per cent. of the animals suffering from the disease have tuberculosis in the milk gland. This, of course, reduces the chance of milk contamination very greatly. Furthermore, milk, as it reaches the consumer, under ordinary conditions, is mixed milk. That derived from one animal is mixed with that from many others, so that if there chances to be one or two animals suffering from udder tuberculosis their milk is almost sure to be mixed with a large amount of milk from healthy animals. Thus the number of bacilli in a sample of milk is greatly reduced.

Such facts, then, indicate that the contamination of the milk and its products is perhaps not very common. But how common? To this question we can give no answer. It has been found impractical to determine by microscopic tests whether milk contains the tubercle bacillus or not. There are methods by which it can be done, but they are at present unsatisfactory and wholly unreliable. The only even approximately satisfactory method of determining whether a given sample of milk is infected with the germs is by inoculating it into the abdomen of guinea pigs. If the milk does contain the

bacilli, even in small numbers, such inoculation is sure to be followed by the disease. This method, of course, is slow. It requires several weeks to obtain results, and it is therefore of no use as a practical method of testing milk. It is, however, a method capable of giving valuable scientific results as to the general infectiousness of milk. It is such experiments with guinea pigs which have led to the conclusion that milk from only such cows as are suffering from udder tuberculosis is dangerous. Similar experiments have been made to test the infectiousness of mixed market milk of cities, with the result of showing that market milk is frequently, though by no means universally, infected with the tuberculosis germs.

Such experiments with guinea pigs are, however, open to very serious criticism, and various considerations lead us to doubt as to their value in indicating a danger to man in consuming such milk. In the first place, it is very certain that the guinea pig is far more sensitive to tuberculosis than man. Indeed, the guinea pig appears to be more sensitive than any other animal yet discovered, and the fact that a guinea pig would succumb to tuberculosis if inoculated with milk, while it indicates that tuberculosis bacilli are in the milk, does not at all indicate that such milk would be dangerous to man. Secondly, most of these experiments upon guinea pigs have been performed by inoculating the milk or butter into the abdomen of the animal, and this is very properly pointed out as a very different thing from using the milk as food. The fact that sensitive guinea pigs will *frequently* succumb to tuberculosis if milk or butter is inoculated into their abdomen, while it does indicate that tubercle bacilli are *frequently* present in these dairy products, is far from indicating that such dairy products are likely to be of any danger to mankind when used as *food*. Some of the experiments with animals, indeed, have been performed by using the milk or butter as food, and these, of course, are more in accordance with the conditions in mankind. Under these circumstances a considerably smaller proportion of the animals suffer from the disease, a fact which indicates, of course, that there is less danger when the tuberculous milk is used as food than when inoculated into the abdomen.

A third series of facts has been recently discovered, which throws even greater doubt upon the whole series of experiments. It has been found that there is present in the milk a

species of bacillus which has considerable resemblance to the tubercle bacillus, but which is not the tubercle bacillus. When studied microscopically, this bacterium cannot be distinguished from the true tubercle bacillus, and if found in milk would undoubtedly be confused with it. Moreover, when inoculated into guinea pigs it produces a disease, and frequently death, with symptoms very similar to those of true tuberculosis. An examination of the body after the animal has died shows the presence of abnormal growths very similar to those produced in tuberculosis itself. Now, these bacilli are certainly quite common in milk and butter, and if butter or milk containing them is inoculated into guinea pigs the animals will die and show some symptoms of tuberculosis. The experiment would be undoubtedly set down as indicating the presence of the tubercle bacilli in the milk. But this bacillus is not harmfull to other animals, and probably not to man. It is certainly not the cause of tuberculosis. Now, the studies of recent months have shown that many of the fatal results in the guinea pig experiments have been caused by these false tubercle bacilli, and not by the true *bacillus tuberculosis*. By further experimentation it is possible to distinguish between these two types of organisms. They grow differently and have different pathogenic powers. Now, recognizing the common presence of this false bacillus in milk and butter, it is plain that the previous experiments of inoculating guinea pigs are open to quite serious question. Some observers have gone so far as to claim that nearly all of the fatal results obtained from inoculating butter into guinea pigs have been due to this false bacillus, and not to the true bacillus. Even those who have been foremost in the inoculation experiments, and in claiming the seriousness of the problem, have acknowledged that many of the positive results have been due to this false bacillus, although they still claim that the true tubercle bacillus produces a certain proportion of the positive results in their experiments. This claim cannot be doubted.

From all these facts it is clear that the method of testing the infectiousness of milk by the use of guinea pigs is open to serious question. This is entirely too sensitive a method of testing, for the guinea pig will succumb to a disease, either tuberculosis or one of a similar nature, from the inoculation of products which would be entirely harmless to man, and in some cases from products which contain absolutely no true tubercle bacilli at all. While, therefore, the inoculation experiments

that have been going on for several years now have indicated that butter in quite a large percentage of the specimens, thirty to forty per cent., contains active bacilli fatal to guinea pigs, and that market milk in considerable proportion also contains them, we must admit that the conclusions thus drawn have little or no relation to the problem of human health, and that they do not indicate of necessity a danger from the milk at all proportional to the seeming results. The general consensus of opinion at the present time appears to be that the danger from the use of milk, as indicated by inoculation experiments, has been certainly very much overdrawn.

To these facts must be added the evidence given elsewhere pointing to the existence of varieties of the tubercle bacillus. If the human bacillus is only slightly pathogenic for cattle, it is at least likely that the bovine variety may not be very dangerous to man, although this remains to be proved.

The same facts arise when we come to study the conditions of tuberculosis in mankind from a statistical standpoint. It must be remembered that the use of dairy products has been quite rapidly increasing in the last fifty years. This is particularly true of England and the United States, and it is true also to a certain extent of other countries. We have seen above, also, that there are very good reasons for believing that the amount of tuberculosis among our cattle is increasing, and increasing somewhat rapidly. If, now, it were a fact that mankind obtained this disease to any appreciable extent from milk, we should expect to find the amount of tuberculosis in mankind increasing, and especially in those countries where there is the largest increase in the use of dairy products. Furthermore, it is a fact that in most European countries milk is not drunk raw to any very appreciable extent. Nearly all of continental Europe has, in the last few years, acquired the habit of sterilizing the milk before using it. In some countries this is almost universal. In Switzerland the children are taught the danger of drinking milk without sterilizing, and at the present time the amount of milk drunk without some kind of preliminary heating is comparatively small in continental countries. On the other hand, in England and in the United States the habit of sterilizing milk has not obtained much foothold. While milk is sterilized frequently for use among infants and invalids, there is no such general custom as in Europe in this direction, and in these countries we may say that the great bulk of the milk is drunk without sterilization. Now if milk were a con-

siderable source of tuberculosis, it would be inevitable that we should find a difference in the statistical results from countries where milk is used raw, and those from countries where it is sterilized.

Now, what are the facts as shown by statistics? In the first place, during the last forty or fifty years there has nowhere been an increase in tuberculosis among men, but a very decided decrease. In Great Britain the decrease in forty-five years has been thirty-nine per cent. In America, in the United States, there has been a decrease of about the same amount. In the continental countries, so far as statistics are comparable, the results are the same. Everywhere among European countries the last half century has seen a very marked decrease in the amount of tuberculosis. Now, this decrease in tuberculosis includes the disease at all ages, among adults and among children. It includes a decrease in all kinds of tuberculosis, the tuberculosis in the lungs as well as in the organs of the abdomen. It is true that the decrease among children has not been so great as it has been among adults, and it is claimed by some that tuberculosis of the abdominal viscera among children has not decreased. Moreover, the decrease in tuberculosis is as great, or perhaps greater, in England and the United States where milk is consumed without sterilization as it is in continental Europe where the milk is practically always sterilized. And, lastly, there is apparently no greater decrease on the Continent in the last few years, since the introduction of sterilization of milk, than in other countries where sterilization has not been so widely adopted. The decrease in tuberculosis has been a constant one, but has been especially rapid since the discovery of the tubercle bacillus. This decrease is attributable to greater knowledge of the disease and to better sanitary conditions. It is found, further, that the amount of tuberculosis is the greatest among poor children, and this is simply connected with the poorer nutrition. The country of Japan apparently has a larger amount of tuberculosis than almost any other country, it being stated that nearly one-third of the deaths occur from this disease. But the tuberculosis in Japan is certainly not traceable to milk, because until within very recent years the Japanese have not used milk as food. Within the last ten years the use of milk has become somewhat common in Japan; previously its use has been almost unknown. Nevertheless, the amount of tuberculosis has been and still continues at this very high per cent.

Taking all of these facts together it is certainly plain that dairy products cannot be regarded as a very prolific source of tuberculosis, and that this danger is far overshadowed by other sources and is practically confined to children. While at the present time there is a considerable variation in the opinion of different bacteriologists upon the question, there is a very manifest tendency toward a minimization of the danger. The general opinion would be somewhat as follows. Milk from tuberculous animals may be infected with the bacilli, if the animal has udder tuberculosis or generalized tuberculosis. Such milk may be dangerous to mankind. The danger, however, is confined practically to young children, adults, except in rare instances, not being amenable to tuberculosis from this source. The fact, however, that the milk of most tuberculous animals contains no bacilli, that the milk is commonly mixed with other healthful milk before it is drunk, that it is taken into the stomach and acted upon by the digestive juices, and that man, especially if in health, has a considerable personal resistance against an attack of the disease, reduces the danger from this source very greatly. Furthermore, when we consider the very decided reduction in the amount of tuberculosis in the last half century, running parallel with the increase in milk consumption, and the increase in tuberculosis among our cattle, we are driven unquestionably to the conclusion that if milk is a source of danger it is one of the small sources of danger, that the vast majority of cases of tuberculosis in man come from other sources than milk. We must regard the danger as existing especially for children, but its extent does not appear to be very great.

II. MEASURES FOR COMBATING TUBERCULOSIS.

We now come to the question, very important for our agriculturists, as to what kind of a battle can be waged against this disease. It is a distinctly agricultural problem, only indirectly concerning the public. At the outset we may ask whether there is a probability that the disease can be eradicated from our herds. It is well known that pleuro-pneumonia has been practically exterminated from cattle. It has been claimed that we may have equal success in eradicating tuberculosis, and in time obtain a set of cattle entirely free from the disease. There are, however, few people, probably no scientists, who have such a hope at the present time. The problem is a very

different one from that presented by pleuro-pneumonia. The disease is so widespread that is is manifestly impossible to expect the slaughter of every animal suffering from the disease in an incipient form. It would mean bankruptcy to agriculture. Moreover, if it is true, as most bacteriologists believe, that the disease can be communicated from man to the animal, it is very certain that there will be a continued source of new cases until the disease is also eradicated from mankind. Considering these difficulties, it is plain that we cannot hope to deal with the subject as we have dealt with pleuro-pneumonia. What may be hoped, however, is that the disease may be reduced in amount and kept down to manageable limits.

In the first place, it is evident that the problem is for our agriculturists a very serious one, a more serious one, indeed, than our American farmers are inclined to believe. It is certainly unwise for our agricultural communities to attempt to shut their eyes to the facts as they exist. It is equally unwise to overdraw the facts and produce undue alarm, either on the part of the farmers or on the part of the general public. The facts as they exist, however, indicate that the problem is a grave one, and that it concerns the agriculturist himself more than it does the general public. It is true that the general consumer is interested in not having tuberculosis brought to him in his meat or milk or butter. But, as we have seen, this source of the disease in man is plainly a very small one as compared to other sources. The public is more interested in the elimination of the other sources of the disease rather than this one from the cow. To the agriculturist himself, however, the problem is a different one, and one really much more serious. The study of recent years has taught that for the health of the public the problem of bovine tuberculosis is less serious than was believed a few years ago, but for the agriculturist himself it is more serious than was formerly recognized.

In the first place, the direct loss that results to the farmer is something quite surprising. We have in our country little statistical evidence in this line, but it has been collected somewhat accurately in Germany, and it was found, for example, that in Germany in the year 1895 there was a direct loss of one and one-half million dollars to the German farmers from the condemnation as tuberculous of the carcasses of slaughtered cattle. When we remember that much of the flesh of tuberculous animals in Germany is not condemned by the in-

spector and, therefore, not comprised in their figures, this loss of one and one-half millions will give us some idea of the extent of the disease and its seriousness. Furthermore, this loss is increasing each year, and here we have statistics that are strictly reliable, because whatever may be said of the efficiency of the veterinarian inspector in detecting the disease, it is certainly a fact that more animals are being condemned in the public slaughter-houses each year and the consequent loss is becoming each year greater. In other countries the statistics are not so easily obtainable, but there is no question that in other European countries the amount of loss is rapidly increasing until it is assuming somewhat startling proportions. This cannot be otherwise, when some countries like Denmark have apparently fifty per cent. of the animals suffering from the disease in some form.

Of course the losses in indirect ways are also very great, but they cannot be estimated in figures. The loss of milk of the animals, the diminution in the fertility of tuberculous cows, the necessity of removing from the dairy herd many a valuable animal which shows the presence of this disease, add to the loss from direct slaughter no small amount. Loss is entailed too, by the increased suspicion of dairy products. Moreover, inasmuch as the disease is apparently on the increase, it is becoming more and more difficult to obtain healthy animals for breeding purposes. It has been pointed out in agricultural meetings in Germany that it is becoming very difficult to get animals free from tuberculosis to serve as breeders for the dairy herd. Veterinarians are pointing out that this difficulty is becoming greater and greater each year, and that apparently, unless the tendency is counteracted in some way, it will only be a few years when it will be an impossibility for a farmer to obtain, for breeding purposes, any animals that are not infected with this taint. In this country the trouble has not by any means reached such a stage, and yet apparently the loss is increasing here also, and unless some means are taken to counteract it we may expect that our farmers will suffer as have the farmers in Europe.

These facts are staring the agriculturists of Europe in the face, and their gravity is becoming more and more recognized. The agricultural boards in general appreciate the great gravity of the situation. They are stating over and over that *something must be done;* that unless in some way it is possible to counteract this increase in the disease the destruction of dairy

industry appears to be almost a matter of certainty. Although here the problem is not so serious, it is wise for our farmers to take into consideration the condition of the problem in Europe, and to remember that we are somewhat slowly, and yet surely, going in the same direction; we should, if possible, use our wisdom, combined with that of Europe, to stem this tide of the disease before it reaches with us a magnitude such as it at present has in certain European countries. The gravity of the problem is then an agricultural one, and it is a subject which the agricultural community is interested in handling. This point cannot be too thoroughly emphasized. While the public at large is certainly interested in keeping tuberculosis among cattle from distributing the disease among men, the problem as affecting the public at large is very slight as compared with the problem as affecting the agriculturist. If tuberculosis legislation is to be designed and adopted, its primary object is for the benefit of the farmer and not for the benefit of the public at large. Incidentally the public at large benefits, and of course must pay its share of the expense, but the primary object of tuberculosis legislation is to protect the farmer's herd and to protect him in the development and the maintaining of the dairy industry.

Are there any means now at our command for settling this gigantic problem? At the outset we may state that up to the present time there is no absolutely satisfactory means which has anywhere been put into practice. Legislation of some sort has been adopted in all European countries. The legislation is quite varied, however, and has varying success. In general, each country endeavors to protect itself against others, and with considerable degree of success. There are in most countries laws which prevent the importation of animals from abroad, except under such strict inspection as to prohibit the introduction of tuberculous animals. This same thing has been adopted in the United States to protect one State from importation from another State. But, while this method of protecting a country against others is moderately successful no country has as yet found any very satisfactory method of protecting itself against the disease within its own borders. We are, however, slowly learning methods of attack, and, as the years are passing, our ability to handle the disease is increasing. In the consideration of this question we must notice two points. First, the method of detecting the disease, and, second, the method of dealing with the herd after the disease has been detected.

DETECTION OF TUBERCULOSIS BY CLINICAL SYMPTOMS.

It is, of course, manifest that there is no possibility of dealing with tuberculosis until we have some satisfactory means of determining the presence of the disease. There are two methods which have been used for indicating its presence. The first is by means of clinical symptoms, and this, for purposes of controlling the disease, is almost useless. A skilled veterinarian is able, by means of clinical symptoms, to distinguish many cases of tuberculosis. Most advanced cases of the disease he will discover, but all of the incipient cases will escape his observation entirely, and many of the cases that are really very far developed show no external signs which the veterinarian can detect. As a result, the method of detecting the disease by means of clinical symptoms is absolutely unsatisfactory, and if we had no other means than this it would certainly be hardly possible to cope with the disease at all. In spite of the most rigid inspection of this sort the disease may run through a herd, many animals will have the disease and distribute it from one to another, and yet the veterinarian be unable to detect it early enough to prevent the disease from being distributed from animal to animal. We must admit, with all veterinarians, all scientists, and all bacteriologists, that the clinical detection of the disease is so unsatisfactory as to be practically useless in giving us adequate means for battling with this widespread disease.

DETECTION OF TUBERCULOSIS BY USE OF TUBERCULIN.

The second method of detecting the disease is the use of tuberculin; and here we come to a problem over which there has been the greatest amount of contention. The opposition has arisen from many sources and for many causes. It is well for us, however, to consider the facts clearly and to notice the condition of things in regard to the use of this much-abused test.

Accuracy of Tuberculin Test. — The first question is in regard to the accuracy of the test. Over this, as over every other point, there has been much dispute, but at the present time there is an absolutely universal consensus of opinion. Tuberculin, as a means of detecting this disease, is very accurate. By this statement it is not meant that it never makes a mistake,

In some instances of advanced tuberculosis the tuberculin fails to give any reaction. These cases are rare, however, and are of comparatively little importance, because when they do occur the clinical symptoms are so well developed that the animal will be condemned independent of tuberculin. If, therefore, we are simply thinking of the matter of the detection of the disease, the failure to detect advanced cases is of little significance. Occasionally it may perhaps fail to detect a case not so far advanced. At the other extreme it has been claimed that there are some animals which react to tuberculin but are not suffering from the disease at all. This is apparently a mistake, although, of course, it is an extremely difficult thing to disprove. There are quite a number of cases of reacting animals in which the disease has not been detected after the slaughter of an animal, but anyone who knows the difficulty of making a thorough examination of a dead carcass will see at once that such evidence is at least unsatisfactory. If the case is an incipient one, the question of discovering it by post mortem examination is almost directly dependent upon how careful a search is made by the veterinarian. Sometimes he will examine an animal for two or three hours without success, but finally, after a search of several hours, will discover somewhere a small lymphatic gland which has evidently become tuberculous. Now, such an animal is certainly infected with the disease, and, bearing in mind that we are only here considering the matter of the accuracy of the test and not its value in other respects, it is very clear that the fact that we do have such cases of seeming mistakes is a simple testimony of its accuracy. It is the general belief among those who have used tuberculin most that if the test is made in a proper way animals do not give the reaction unless they have the disease at least in an incipient form. If the test does give a reaction in animals that have seemed to have no signs of the disease, this is because the disease is so incipient that it escapes the attention of the inspector. If there are cases where a healthy animal reacts, such cases are at all events extremely rare, and probably due to improper use of the tuberculin. But to be of value the test should be used only by persons skilled in its use. For various reasons there is a growing belief that it should be used only under the direction of veterinarians or officials. In detecting the presence of tuberculosis in our animals, then, tuberculin is very accurate; too accurate, indeed, to be a guide for the indiscriminate slaughter of reacting animals.

Injurious Effects of Tuberculin. — It has been, from the first, thought by some that the use of tuberculin produces a direct injury upon the inoculated animals. This, however, is undoubtedly a mistake, and there is no longer any belief anywhere on the part of scientists that the injury thus produced is worthy of note. In the first place, the idea that it may produce the disease in a perfectly healthy animal by the inoculation is absolutely fallacious. The tuberculin does not contain the tubercle bacillus, and it is absolutely certain that it is impossible to produce a case of tuberculosis in an animal unless the tubercle bacilli are present. The use of tuberculin, therefore, certainly can never produce the disease in the inoculated animal.

It has been more widely believed, however, that the inoculation of an animal with this material has a tendency to stimulate an incipient case of tuberculosis. It has been thought that an animal with a very slight case of the disease may, after inoculation, show a very rapid extension of this disease and be speedily brought to a condition where it is beyond any use. The reasons given for this have been the apparent activity of the tuberculous infection in animals that have been slaughtered shortly after inoculation. This has been claimed, not only by agriculturists who have not understood the subject well, but also by veterinarians and bacteriologists. But here, too, we must recognize that the claim has been disproved, and that there is now a practical unanimity of opinion on the part of all who are best calculated to judge, that such an injurious effect does not occur. Even those who have been most pronounced in the claim that there is injury thus resulting from tuberculin have little by little modified their claim, until at the present time they say either that the injury which they formerly claimed does not occur, or that the stimulus of the disease is so slight that it should be absolutely neglected, in view of the great value which may arise from the use of tuberculin. Apart from two or three who hold this very moderate opinion, all bacteriologists and veterinarians unite in agreeing that there is no evidence for believing that *any* injury results. In Denmark, especially, many hundreds of thousands of animals have been inoculated, and the veterinarians say there is absolutely no reason in all their experience for believing that the tuberculin inoculation is followed by any injurious results.

Abuse of Tuberculin. — It is certain that the use of tuberculin is subject to abuse. The abuse, however, arises rather

from its use in the hands of ignorant or unscrupulous individuals than in its use in the hands of officials. It has been shown that an animal once inoculated and showing the characteristic reaction of the disease is then, to a certain extent, protected from a second inoculation. If this animal be now re-inoculated it will frequently, though not always, fail to show a second reaction until after a number of weeks or a number of months have passed. This fact has led in some countries to a fraudulent use of the tuberculin, as follows: An owner of a large herd will have all his animals privately inoculated with tuberculin. He will then select all the animals that do not react to keep, while all the reacting animals will be at once rushed to the border of the country for exportation. When they are to be imported into another country, according to the laws in most European states, they must be inoculated and only the non-reacting animals imported. But most of these animals having recently been inoculated are protected from the second inoculation, and the official test at the boundary fails to show the presence of the disease. They are, therefore, accepted as free from tuberculosis, and thus by this fraudulent means tuberculous animals are to a certain extent freely sold. Of course the remedy for this is not difficult to find. In Belgium there is a law forbidding the use of tuberculin by the private individual, and making it only possible to use it under official inspection. After such official inoculation the animals that react are marked by a notch in the ear, and from that time on anyone who sees them knows perfectly well that the animal has had tuberculosis, whatever be the result of the tuberculin test at the moment. It is not possible to emphasize too greatly the importance of this marking of animals. Every animal that has once reacted should be marked in such a way that the mark cannot be obliterated. Apparently, then, the only proper use of tuberculin must be in the hands of officers who understand its use and who will honestly use the test and properly mark all reacting animals. In this way only can the purchaser of cattle be properly protected.

INCREASE IN USE OF TUBERCULIN.

The use of tuberculin is certainly extending more and more widely every year in all European countries. There has been there the same objections to its use that there has among our own farmers. These objections have been partly well founded

and partly due to prejudice. In the first place, many of the farmers refuse the use of tuberculin, for the simple reason that they are afraid to know to what extent tuberculosis may be present in their herds. They fear that if it is known that they have a number of cattle in their herd that are infected with the disease it will be difficult for them to sell their milk, difficult for them to dispose of their cattle, and they will suffer financially from the test. They prefer to remain in ignorance and to use their animals freely as if all were healthy. This has undoubtedly been the basis of a large part of the objection to the use of tuberculin. Moreover, in some countries, and especially is this true in our own, the customs and laws have been such as to demand the immediate slaughter of all animals which react to the tuberculin test. The objection to this is too well known to need emphasis. The farmer's good sense has told him that it is needless and that it means an unnecessary waste. When, as the result of a tuberculin test, there are slaughtered a number of animals, several of which show only such a slight trace of tuberculosis as would be indicated by a single small tuberculous nodule, the farmer very rightly feels that he has been subject to trouble and to financial loss which was not demanded by the condition of things. He has rightly claimed that such animals need not be slaughtered. They are not sources of danger to the public, and perhaps not sources of danger to his herd. The farmer then blames the tuberculin test, when the blame should have been upon the law demanding the indiscriminate slaughter of reacting animals. The tuberculin test picks out too incipient cases to justify the slaughter of all animals thus reacting. This fact, coupled with the fear on the part of the farmer to know the condition of things in his herd, probably explains *all* of the real opposition that has arisen to the use of tuberculin.

The objections thus arising, however, come not from the use but from the abuse of the tuberculin test. The use of tuberculin should be for the purpose of determining the presence of the disease, and thus benefiting the farmer rather than doing him an injury. When the tuberculin is used properly, as it is now more and more rapidly being used in European countries, the farmer is universally benefited and never injured by it. He is always the gainer and not the loser. When the farmers find out, as they are gradually doing, that the test simply enables them to pick out the tuberculous animals and does not force them to lose by slaughter a large number of

animals that are still valuable, they cease to find so many objections to the use of the test, and gradually learn that it is decidedly for their advantage to have their herds tested in order that they may be on a better vantage ground to protect their herds for the future. The result is that in Europe the objections to the use of tuberculin have very largely disappeared, and are disappearing now even more rapidly. If the legislation had not been too precipitate in early years and demanded the indiscriminate slaughter of all reacting animals, it is doubtful whether any of the great opposition to the use of tuberculin would have developed. At the present time the use of tuberculin is coming to be made simply to detect the presence of the disease, so as to give the farmer, in conjunction with the veterinarian, the data upon which he can successfully, and without too great inconvenience and too great expense, deal with the subject of tuberculosis and free his herds from this curse in the future.

In general, then, the use of tuberculin is increasing, and its value is becoming every day more and more appreciated. It enables the farmer to pick out the animals which he must deal with as suffering from the disease, either in an incipient way or in a more advanced stage, and gives him a chance to battle with the disease in a successful manner. It is the one successful means of detecting the presence of the disease, but the veterinarian and the scientist are learning more and more clearly each year that it should not be used for detecting animals for the purpose of indiscriminate slaughter.

METHOD OF DEALING WITH THE TUBERCULOUS HERD.

The next question is how the farmer can deal with a herd after tuberculosis has once obtained entrance to it without too great expense and with promise of successfully handling the problem. Every attempt to get rid of tuberculosis from the herd of cattle must begin with the tuberculin test. There is very little chance for the farmer to get rid of the disease after it is in his herd, except either by getting rid of *all* of his herd and starting absolutely new, or by beginning with the tuberculin test and thus discovering *every* case of tuberculosis, even in the most incipient stage. Thus, and thus only, can he start in his attempt to purify his herd with a fair hope of success. After the tuberculous animals have once been designated in this way, the problem of what to do with them is still a se-

rious one, but one which is capable of solution. The first methods that were used were undoubtedly too severe, for, as is well known, they involved the slaughter and absolute destruction of the flesh of every animal that reacted to the tuberculin test. Such a method was too expensive to make it at all feasible. When we remember that from forty to fifty per cent. of the animals in certain countries will respond to the tuberculin test, it is perfectly manifest that such a measure would there be ruin to the dairy industry. It is simply an impossibility, and that it is an impossibility has been clearly shown by the fact that in two instances in which an attempt was made to enforce such laws, namely, in Massachusetts and in Belgium, it was necessary to abandon them. Moreover, for reasons which have already been pointed out, it is apparently needless.

Another suggestion has been adopted in certain European countries, namely, that the reacting animals must be separated from the non-reacting animals, and must be then brought to slaughter within a year. This gives the farmer time for proper fattening of the animals and for bringing them to the condition of slaughter so that he need not have the loss that would result from immediate slaughter. Of course he must run the risk at the end that when slaughtered the animals will be found so decidedly tuberculous that their flesh will be condemned, and thus the expense of the fattening will be a loss. But, inasmuch as in European countries the flesh is not all condemned from incipient tuberculosis, it will in most cases result that the animals thus fattened will yield a tolerable return to the farmer and not be total losses.

But even this less radical measure appears to be unnecessary and is not very highly regarded in the different countries of Europe. The fact is, that the more experience accumulates the more we learn that many of these incipient cases of tuberculosis are only temporary, and that the animals in question, if kept in a favorable condition, will soon recover and may live many years of useful life. It is, of course, not very easy to give accurate data in this regard, but the best data obtained have been those of Prof. Bang in Copenhagen, where for several years there has been under very close observation a large herd of animals which had at the outset a very high per cent. of tuberculosis. The animals were all inoculated with tuberculin and subsequently kept under observation for several years. Many of them after a time ceased to respond to the subsequent tests. In later years, as they were slaughtered

one by one, it was found by post mortem examination that quite a number of these animals that had in earlier years reacted to tuberculin test and had failed to react in later years showed that they had actually had the disease, but that the disease had been arrested, the animals had apparently recovered completely, and at the time of slaughter were in a healthful condition so far as concerned this disease. Now, it is impossible to fail to draw the conclusion from such facts that it is entirely needless to slaughter all animals that react from tuberculin, when we remember that many of them would still live for years without any advance of the disease, and others would probably completely recover. It is simply a question whether these animals can be prevented from contaminating the rest of the herd.

Various suggestions have been made in connection with the building up of a healthy herd. One is that no person shall purchase animals that have not been inoculated and by this test proved to be healthful. There is no question that this deserves the very greatest emphasis and should be most highly recommended. It is certainly true that our farmers, as a rule, *buy* their tuberculosis. The herd, originally free from the disease, is increased by purchase of animals that have not been tested, the purchased animals bring the infection into the herd, distribute it, and in a short time the farmer suffers. It can not therefore be too strongly emphasized that the farmer, if he wishes to keep his own herd in a healthful condition, should, where it is possible, insist that the animals that he buys shall be first tested with tuberculin and proved to be free from the disease. It has been suggested, also, in agricultural circles in Europe, that a general rule should be adopted that no premiums should ever be given to animals in the agricultural exhibits until after the animals are inoculated with tuberculin and proved to be free from the disease. Of course the animals which obtain the premiums are of special value and will in the future be used for breeding. If, therefore, no premiums are given except to animals that are tested and proved to be non-reacting, there is here one strong safeguard against the further distribution of the disease.

There is, however, at the present time prominently before all agricultural communities, as well as scientific men, one method of dealing with the tuberculous herd which appears to be not only moderately successful but quite satisfactory, and gives promise of the most excellent results with a mini-

mum expense. This method is the well known method of Prof. Bang, developed in Copenhagen, and now extending itself over Europe. It is universally spoken of in high terms by bacteriologists and veterinarians who know anything about its results. They recommend it as the only feasible method yet devised for meeting the problem. The object of the method is to enable the owner of a herd of cattle infected with tuberculosis to obtain a healthy herd without subjecting himself to much of any expense, and with a minimum of inconvenience. The general method is well known, but a description of its application may not be out of place here. The method of Prof. Bang is as follows:

1. The farmer consents to follow out accurately directions given him by the veterinarian. This is a primal necessity, because if the directions are not followed out with strict accuracy the whole plan is absolutely useless.

2. After the farmer has consented to the proper conditions, the whole herd is tested with tuberculin and then the animals separated into three sections.

3. The first section contains those that neither show clinical signs of tuberculosis nor react to tuberculin. These are presumably healthy and are put into a barn by themselves. This barn must, if previously occupied, be disinfected before the healthy animals are put into it.

4. The second section contains those that show clinical symptoms of the disease such as to indicate an advanced case of tuberculosis or such as show tuberculosis in the udders. These animals are slaughtered *at once*, submitted to proper inspection and the flesh used or destroyed in accordance with the verdict of the inspectors.

5. The third lot contains the animals that are apparently healthy, with no external signs of tuberculosis, but that have reacted to the tuberculin test. These are presumably animals with incipient tuberculosis. They are put in a separate barn and kept absolutely isolated from the healthy herd.

The isolation of these two lots of animals from each other must be absolute, though it is not necessary that they should be in separate buildings. In the barn where the first experiments were made there was a long cattle barn with some two hundred animals in it. After the inoculation a partition was built in the barn separating it into two divisions, in one of which were kept the healthy, and in the other the reacting, animals. This partition absolutely separated the two herds from

each other, but did not require the building of any new cattle stalls.

6. These two herds, after the separation, must be kept absolutely isolated from each other. They are never allowed to come together, never allowed to drink out of the same troughs, and, so far as possible, are attended by different attendants, so that persons going from the infected herd can have no chance for carrying the disease into the healthy herd upon his boots or clothing. The animals are used as usual, but the milk from the reacting herd is, as a rule, sterilized before being used.

7. The calves which are born from animals in the reacting herd are, after the first three days, separated from their mothers and are brought up wholly on sterilized milk. Before these calves are allowed to associate with the healthy herd they are themselves inoculated with tuberculin, and, of course, if they show any reaction they are kept from the healthy herd, and either slaughtered or put with the reacting herd.

8. After six months the animals in the healthy herd are inoculated again, and any who now show a reaction are removed at once and put with the reacting herd. This process is repeated every six months under proper supervision, and in all cases the reacting animals are separated from the healthy herd and put with the others.

9. No animal that has once entered the reacting herd is ever put back among the herd of healthy animals, even though it may show evidence of having entirely recovered.

As this process is continued year after year the animals in the reacting herd are gradually gotten rid of as they get old or as they are bought to slaughter; the healthy herd is always increased by animals that are shown to be free from the disease, and thus the expectation has been that the healthy herd will gradually increase while the reacting herd decreases, until finally the disease will practically disappear. The only expense to the farmer in all this would be that of building the partition in the barn and of seeing that the animals are kept isolated from each other. The State itself in these experiments undertakes the expense of furnishing the tuberculin and performing the inoculation.

This, in general, has been the method adopted by Prof. Bang, and now in use under his inspection for several years. The results have been very favorable. The partition in the barn under Prof. Bang's inspection is changed year after year

as the size of the two herds of healthful and reacting animals change. It has been found necessary each year to move the partition in such a way as to make the reacting herd smaller and smaller, while the healthy herd is larger and larger.

The results are shown in the following table:

Year.	No. of animals in reacting herd.	No. in sound herd.	No. re-acting in the sound division.
1892......	131	77	——
1893......	90	103	10
1894......	81	122	2
1895......	69	136	3
1896	54	149	7
1897......	48	155	6

It will be seen that while the number of the reacting herd has decreased from 131 to 48, that of the sound herd has increased from 77 to 155. It will be seen also that each year a few of the animals left in the sound herd become infected, but that the number is small. Evidently this herd is slowly getting rid of the disease.

The same method has been adopted quite widely in the dairy herds in Denmark, and the results in general have been similar to those obtained under the personal direction of Prof. Bang. But they have not been universally successful. In some cases the decrease in the reacting animals has been very slow, in other cases it has been hardly noticeable. In most of the herds, however, it has been possible to show that the cause has been the fact that the farmer has failed to obey the directions for careful isolation; that in some way, either by having the door in the partition between the two stalls, or by having the same attendants, or by some other means, there has been communication between the reacting herd and the healthful herd. Under these circumstances the disease has been carried from the one to the other and the healthful herd has, therefore, been constantly infected. It is certainly a fact that even under the best circumstances new cases of tuberculosis occasionally occur in the reacting herd, indicating, of course, some source of contamination either from the other animals or from the attendants. But in spite of this partial failure the method has been in general very successful, and is apparently now in such successful operation in many places in Denmark that the farmers are slowly getting rid of tuberculosis from their herd.

The process is, of course, slow. A quicker way would doubtless be to kill at once all the reacting animals. But the merit of the method of Prof. Bang is that it is done at an expense so small as to be hardly worth consideration.

The success of this method as adopted by Prof. Bang in Copenhagen has been so great as to excite general interest all over Europe. Many of the bacteriologists and veterinarians of European countries have visited Copenhagen for the purpose of seeing the method actually in operation, and all of them come back with the belief that the method thus developed is the only one that is practical and which bids fair to be a means of successfully combating this disease. At the present time this method is being recommended almost universally in European countries. Illustrative experiments are being started in other countries for the purpose of showing the farmers by demonstration how the method works. The expenses of the inoculation are in general borne by the public funds, and not by the farmer, and it is a rapidly growing belief that this method as devised by Prof. Bang is practical, and if applied with wisdom will enable our farmers to handle the subject in such a way as to rid their herds at least in large measure of the disease without any great expense to them, and with a minimum of trouble.

In these experiments it has been found, not unnaturally, that there has been greater success with young farmers than with older ones. The young farmer is more open to conviction of the value of the method, more ready to learn methods and applies them with stricter accuracy. The older farmer cannot so easily be taught new methods. As a result the young farmer will almost always succeed in improving the condition of his herd in this way, while the older farmer has less success. It has been abundantly shown, however, that eternal vigilance is absolutely necessary. If the farmer becomes careless, the whole procedure becomes useless, half-way methods being as good as none.

The best method of introducing this procedure among farmers is, perhaps, not as yet definitely settled in different countries. It seems to be a general belief that the adoption of this method of Prof. Bang must be at first voluntary on the part of the farmers who are interested in the subject. If it was made compulsory it would be a failure. It can only succeed where the farmer has interest enough to lead him to adopt and carry out strictly the rules for isolation given him. If it

were a matter of law instead of volition the farmer would fail to give it personal supervision, and the experiment would fail in such a large majority of cases as to bring the whole plan into disrepute. It will only succeed where the farmer will take a personal interest in the carrying out of the scheme. It is hoped, however, after a few years had demonstrated by examples in numerous localities the feasibility of the plan, that legislation looking in this direction might be feasible. At the outset it would be futile. It is, however, a general belief that the expenses connected with preparing the tuberculin for the inoculation of the animals should be free to the farmer. This is advisable for two reasons. In the first place, it will make the farmer much more inclined to adopt the scheme than if the original inoculation were a matter of expense to him; and, secondly, it insures that the tuberculin and the methods of inoculation used are satisfactory inasmuch as they will be under official inspection. Already two or three of the European countries have advanced as far as this, giving the free use of tuberculin to such farmers as are willing to adopt the methods suggested along the lines indicated above.

One of the most important phases of the adoption of this method of Prof. Bang is that the young animals should be inoculated. This is of so much importance that it deserves to be considered by itself and should be recommended entirely apart from the general adoption of the method of Prof. Bang. The testing of young cattle by tuberculin will detect at once the animals which have already yielded to tuberculosis. These animals, above all others, should be excluded from the herd. If they have taken the disease in the earlier period of their life, it is practically certain that the disease will advance in them rapidly. They will not only be of no use to the herd in the future, but will become a menace to the rest of the animals. Even if they should recover from this attack, the fact that they have yielded to the disease early in life shows that they have weak resisting power. On the other hand a slaughter of such young animals is not a matter of such serious expense as it is later. The flesh can be sold with proper precaution, and the animals have not yet become valuable as dairy animals. It is, therefore, above all things desirable, if a farmer desires to free himself from this great burden, that *all* calves should be tested with tuberculin, and no calf should ever be allowed to join the healthy herd until it has proved by failure to respond to this test that it is free from every taint of this disease.

It is quite a confident expectation on the part of European scientists that the method as outlined here and as is now being slowly adopted, is practical, and is destined to be successful. The European agriculturists and bacteriologists are promising to the farmers that if they will only adopt this method *and carefully follow it up*, they may expect the practical disappearance of tuberculosis among their herds inside of ten or fifteen years. That the disease will absolutely disappear is not expected, but it is a confident belief that by the use of the method as suggested by Prof. Bang it can be in a comparatively few years so reduced in amount that it will not be a menace to agriculture. The significant point in regard to the whole is that this reduction in the tuberculosis can be accomplished with a very small expense to the State for veterinary services, and with practically no expense to the farmer beyond that of dividing his cattle into two herds and keeping them isolated from each other. It is evident that this method of Prof. Bang is more readily applicable to a large herd than a small one. A farmer who owns only two or three cows has a very different problem from one with a large herd. He is less likely to have the disease in these animals and may probably deal with it better by slaughter than an attempt to isolate a single cow.

USE OF ANIMALS REACTING WITH TUBERCULIN.

Meantime, the question arises as to how the animals in reacting herds shall be treated, whether their milk can be used and whether they can be slaughtered for food as can the animals in the untainted herd.

The answer to this so far as concerns the use of the flesh of these animals is very simple, although it may demand certain new regulations at least in most parts of our own country. As we have already seen, there is no reason for rejecting the use of the flesh of an animal that is suffering from an incipient case of tuberculosis. With a proper inspection it is perfectly clear in the light of the evidence that has accumulated in the last five years, that the flesh of animals in the reacting herd may be sold and eaten. If it is to be thus sold, however, there is needed a certain amount of inspection of slaughtered animals. This requires that the flesh be slaughtered in public slaughter-houses or at all events under the direction of public inspectors. To what an extent this is possible in different states of our country is not a question to be answered at this place, but in

the European countries such an inspection is almost universal, and under such conditions there is no reason in the world why the animals in the reacting herd should not be used for food just as freely as are the animals in the non-reacting herd.

Again, the question as to whether the animals in the reacting herd should be used for breeding purposes is one of some importance. There seems to be no reason for rejecting absolutely the animals born in the reacting herd. As already indicated tuberculosis is only in very rare instances hereditary, and if the calves from the reacting animals are separated from their mothers by the third day, and are then brought up upon boiled milk there is no reason for thinking that they are likely to have tuberculosis. It is, of course, possible that they may have inherited from their mothers a slightly increased tendency to take the disease. The fact that the mother had tuberculosis indicates that her power of resistance against the disease was less than that of the animals in the non-reacting herd. It is quite possible, therefore, indeed probable, that her calves may in a similar way be more prone to take the disease than the calves from the non-reacting herd. Where it is possible, therefore, to use the animals from the reacting herd for slaughter while young, and retain only those from the non-reacting herd for the dairy and for breeding purposes in the future, such a procedure is certainly advisable. But it is not necessary, and with the precautions of rearing calves upon boiled milk and testing them with tuberculin before they are milked, with the non-reacting herd, there are no sufficient reasons why such calves should not be kept for future purposes.

USE OF MILK OF COWS REACTING WITH TUBERCULIN.

A much more puzzling question arises, at least in this country, as to the use of the milk of the reacting herd. In Europe this question is one of less importance from the fact that the habit of sterilizing the milk has become so widespread. In such places the problem is already solved. There is no doubt that the sterilization of milk destroys all danger of tuberculous infection, and in Continental Europe it is only necessary to say that the milk from the reacting herd must be sterilized, or at least pasteurized before it is used. The use of sterilized milk is becoming more and more common in European countries, and, therefore, the problem as to the distribution of tuberculosis by means of milk is disappearing. All of the younger

doctors in the European countries are taught the necessity of sterilizing milk, and, to a greater or less extent, even the children are being taught the same fact in the schools. The result of this is certain to be that in a very short time the sterilization of milk for drinking purposes will there perhaps be almost universal; so that the problem as to what can be done with the milk from the reacting herd is already practically solved in continental nations.

In England and the United States, however, the problem is a very different one because, at least at the present time, the practice of sterilizing milk has not extended widely, and the largest part of the milk which is used as food is used without sterilization. What can be done in these countries with the milk from the reacting herd is, therefore, a more puzzling question than in countries where sterilization is common. The same question confronts continental nations in the use of butter which is commonly made from unsterilized cream. From what has already been pointed out it is clear that the danger of distribution of the disease through milk or butter is very slight, even where the milk is used raw, and that there is no statistical evidence for indicating that even in England and the United States milk has been to any considerable degree a source of tuberculosis in mankind. Under these circumstances it seems that, even in these countries also, with a certain amount of precaution, it may be perfectly safe to recommend that milk from the reacting herd be used. It is, however, necessary that certain precautions should be taken. In the first place, all animals suffering from generalized tuberculosis, showing clinical symptoms of the disease, such as emaciation and cough, and, secondly, that all animals showing the slightest trace of an udder disease, should be excluded even from the reacting herd. Such animals are certainly a menace to the public health, as well as the health of the herd. They must be slaughtered and consequently rigidly excluded from any chance of sending their milk to the public. Every one will recognize the necessity of this, even those who are inclined to put the danger from tuberculosis through milk at its minimum. No one will question that an animal suffering from an udder disease, whether it be tuberculosis or otherwise, or that an animal in the later stages of tuberculosis, should be prevented from furnishing the public with milk.

With this precaution it is perhaps impractical and unnecessary to limit further the use of the milk from the reacting herd.

Beyond question it is desirable and perhaps necessary to recommend that for young children the milk should not be used raw, but this recommendation is dependent not simply upon the matter of tuberculosis, but upon other factors. As is well known, milk distributes other diseases besides tuberculosis, such as scarlet fever, diphtheria, typhoid fever, etc. A young infant is extremely sensitive to the attack of various diseases, and under these circumstances in modern times it is certainly unsafe to feed a young child upon raw milk. For other reasons, therefore, entirely apart from tuberculosis, it is necessary that the necessity of pasteurization of milk for infants should be strenuously urged. Year by year, even in the United States, this habit of pasteurizing or sterilizing milk for infants is becoming better understood and more used, and with it the danger from tuberculosis and other diseases distributed by the milk is disappearing. For adults, as we have already seen, there appears to be practically no danger of tuberculosis as derived from milk that is used as food. That there is absolutely no danger is not claimed by anyone, but the danger is very small in comparison with the very many other sources of contagion to which the adult is constantly exposed. When we remember that an adult is almost constantly exposed to tuberculosis by breathing, it is plain that we are not going to increase his safety to any considerable extent simply by advising him not to drink milk which may under rare circumstances contain some tuberculosis germs. The danger from this source is so small, compared to that from other sources, that it does not materially increase the probability of his taking the disease. With the precaution, then, that animals suffering from udder diseases be excluded from furnishing milk to the public, and that the milk that is used for infant feeding be pasteurized or sterilized, there seems to be, according to the best knowledge of to-day, no reason why the milk from the reacting herd should not be used as well as the milk from the non-reacting herd.

Of course, if this method is adopted it will not be very long before the general tendency of business produces a different condition of things. It will not be long before the farmer who has thus separated his herd into a reacting and a non-reacting lot will sell the milk from the non-reacting lot at an advanced price, and use the fact that every animal that furnishes the milk has been proved to be free from the disease as a means of advertisement. This will probably in time result in the

gradual exclusion of the non-reacting herd. The farmer will, of course, seek to get rid of the animals in the reacting herd as rapidly as he can do this without loss, and in time the reacting herd will probably very largely disappear. All of this will, of course, hasten the reduction of the number of reacting animals.

It must not be understood that the conservative recommendations that have been here suggested are universally agreed upon by bacteriologists or veterinarians in Europe or elsewhere as sufficient. Very much more drastic measures are frequently suggested and advised. There are still those who insist that all animals reacting from tuberculin should be slaughtered; that under present conditions of things it is unsafe to use the flesh of such animals under any conditions, that slaughter-house inspection cannot be enforced sufficiently to make it safe; and that it is absolutely unsafe to recommend, even tentatively, the use of the milk of animals that have reacted to the tuberculin test. It is pointed out, and of course properly pointed out, that it is impossible to tell when such a reacting animal may acquire tuberculosis in the udder, and, even though at the time of inoculation the disease may be incipient and the milk healthful, it is perfectly possible that at any minute the disease may become located in the milk gland and the milk become contaminated. These are, of course, undoubtedly, facts, and tend to increase the question as to how safe it is to use raw milk of reacting animals, even under any conditions. Nevertheless, the present indications that the number of cases of tuberculosis as derived from milk is so small, and the almost universal opinion that such cases are confined to children, lead to a growing belief that the milk of reacting animals may be used, if precautions are taken to ensure its pasteurization or its sterilization, for use by infants.

III. PRACTICAL CONCLUSIONS.

There are several practical conclusions to be drawn from the facts as they have been pointed out in the previous pages, and, while these conclusions have already been mostly indicated, a summary of the more important may not be out of place.

If a farmer owns a herd free from tuberculosis he wishes to know how to preserve it in this condition. His only sure

method of doing this is by adopting some such rules as the following:

1. Never allow new animals to enter the herd unless the tuberculin test has shown them free from the disease.

2. If skim-milk is obtained from a creamery, do not feed it to calves (or pigs) without boiling.

3. Do not allow strange animals to mingle with the herd or enter the stalls occupied by the healthy animals.

4. Do not allow consumptive persons to attend the cattle or prepare their food.

These rules will probably keep the disease away from the herd. The rule to buy no animals without the guarantee of the tuberculin test is the most important one of them all.

The farmer who already has the disease in his herd wants to know how to get rid of it. To do this he must build up a healthy herd. This is to be done as follows: In the first place, the task of eradicating tuberculosis from our herds must begin with the farmer and cannot begin with legislation. It is the farmer who is interested in the herd which he owns that must start this conflict with tuberculosis. Legislation may assist. Legislation may direct and advise, but unless the farmer himself takes the subject in hand and begins the battle, legislation will be very largely futile. Second, the key to the whole problem of getting rid of tuberculosis in our herds is isolation, and not universal slaughter. If we can isolate all animals as soon as they show even incipient signs of this disease from the others, we have every reason to believe that we can soon reduce the trouble and bring it within manageable limits. This isolation simply means a separation of the animals from the others, and does not mean their slaughter or their loss. It means simply that they are prevented from contaminating the rest of the herd.

For the purpose of this isolation there is only one promising method of attack, and that is by the use of tuberculin. Clinical symptoms alone are not sufficient. Tuberculin is perfectly satisfactory for this purpose, since it will, beyond question pick out every case of incipient tuberculosis and thus give the farmer data by means of which he can undertake this isolation for the purpose of getting rid of the disease. Without the use of tuberculin there is little use for the farmer attempting anything. He must let things drift from bad to worse, only picking out the worst cases.

This isolation of the animals must be complete, it must be

accompanied by care in building up the herd. Not only must the reacting animals be kept from contact with the healthy herd, but animals in the healthy herd that show any suspicious symptoms, cough, foul breath, nodules under the skin, diseased udders, swollen joints, etc., should be at once removed. At intervals of six months the tuberculin test should be repeated in the healthy herd. Care should be exercised in purchasing new animals, and each fresh animal should be tested with tuberculin before being admitted to the herd. Strange cattle should be kept out of the barn and cattle-yards. All calves should be tested before being admitted to the herd, and, so far as possible, the calves that are retained should be those from healthy animals, which have probably greater resistance to the disease than those from reacting animals. This isolation should also be attended with care in regard to the health of the attendants, and, until we know more definitely that the variety of the bacillus found in man is different from that in cattle, it is eminently desirable that the attendants that wait upon the animals or prepare their food should themselves be free from tuberculosis, and spitting in the barn or cowyard should be strictly forbidden. One bacteriologist goes so far as to say isolation will never be of practical use until the attendants themselves are tested with tuberculin and the reacting attendants isolated.

Isolation should be accompanied by frequent disinfection. Before the non-reacting animals are put into a barn by themselves this barn should be disinfected, and whenever the partition which separates the two herds from each other is removed, this should be accompanied by thorough disinfection. Indeed, so long as there is any tuberculosis in the herd, disinfection of the cow stalls should follow at certain intervals. The details of this matter of disinfection must be left to a veterinarian's suggestion.

Beyond question the farmer will be much aided in his struggle to build up a healthy herd if he can give his animals more air and light. Light is one of the means of destroying tubercle bacilli, and good fresh air and plenty of it is one of the best protections that the animal has against acquiring the disease. An animal that uses his lungs constantly, breathing large quantities of fresh air, is very much less likely to take the disease than one that uses the lungs not so vigorously and breathes more or less impure air. Better hygienic conditions will help keep a herd healthy, but the farmer must not believe

that they alone can get rid of the disease after it is once in the herd.

When the question comes to each farmer as to the proper method to be pursued on his farm there must, of course, be left much room for individual conditions. The isolation method adopted by Prof. Bang is evidently adapted to a large herd, but not to a small one. If a farmer has half a dozen cows, one of which is tuberculous, it is manifestly an absurdity to adopt the isolation method for the one cow. It would be much cheaper to slaughter the animal outright. Thus in all cases the farmer must choose the most feasible method for his conditions. But he must remember that the only method by which he can preserve his herd is not to allow any animal that reacts to tuberculin to associate with his perfectly sound animals. If he has such reacting animals in his herd, whether the herd be large or small, he must suffer loss, and he must himself decide whether he chooses the loss from immediate slaughter, or the slight expense of isolation, or the greater and more lasting expense of the spread of the disease through his herd from the reacting animal as a starting point.

The practical difficulty in the way of eradicating tuberculosis by this simple method is in the lack of interest on the part of the farmer. While some of our agricultural communities have become quite agitated over the matter, the great bulk of farmers are not interested in it and have no desire to do anything in the matter. They do not want any legislation, nor do they want any extension of the tuberculin test. They do not appreciate the gravity of the matter to themselves; they do not feel that the disease is threatening agriculture, especially if it has not happened to attack their herd. As long as such lack of interest is found among our agricultural communities it is hardly possible to hope for any successful combat against this serious menace. For that purpose, probably the most important thing that can be done at the present time is to *educate* our farmers as to the condition of things. If the farmer can be brought to understand thoroughly that this disease is one that threatens him, that it is increasing in our midst, that it means a great financial loss to him, that it is bidding fair seriously to injure the dairy industry — if the farmer can once be brought to understand thoroughly these facts which have now become sadly demonstrated in the agricultural communities of Europe, then he will be ready to accept the simple methods of combating the disease which are being

pointed out. Those, therefore, who are interested in the subject of tuberculosis should lose no occasion to emphasize to the farming community the significance of the problem from the standpoint of the farmer. Anything in the way of distributing information will be a step toward the final conquering of this disease. But tuberculosis cannot be conquered by our agricultural community until its significance from the standpoint of the farmer is thoroughly appreciated.

It is very clear, moreover, that the longer we wait in this connection, the greater will be the problem. There seems to be little question that tuberculosis is increasing in spite of the difficulty in interpreting statistics. It is, at all events, an almost universal belief that this is the case in Europe, and probably also in America. If the disease in our herds is increasing as rapidly as seems to be true, it is perfectly clear that the longer the farmers wait before attempting the active campaign against tuberculosis, the greater will be their difficulty in waging the battle, the greater will be the expense to which they are subjected, the greater will be the loss that devolves upon them, to say nothing of the loss which devolves upon the public at large. It is extremely desirable, therefore, that our agricultural boards should use every endeavor to bring the facts to the attention of our farmers, and that speedily, in order that the contest against the disease may be taken up as soon as possible, and that thus the battle may be made easier and the success less expensive and more sure.

LEGISLATION.

This is not the place for suggestions as to legislation in regard to the matter of tuberculosis. Every nation of Europe and every State in this country has adopted some sort of legislation, but the great difference in the laws that have been adopted show wide differences of opinion as to the possibility and the feasibility of handling the matter through public statute. There is no question, however, that some things should be done by legislation. Legislation is demanded to a certain extent by the farmer, but even more by the public. The only suggestions that it may be wise to make at this place are that legislation should at all events be directed toward three points:

1. Public legislation should in some way insure such an inspection of flesh as to make it possible to use the flesh of

reacting animals without danger to the public and without too great loss to the owner. This, of course, should be along the line of public slaughter-houses and public inspectors of meat.

2. Legislation should be such as to make it impossible that milk from an animal suffering from udder tuberculosis or from advanced generalized tuberculosis should be distributed freely to the public for consumption.

3. Legislation should be devised which shall look toward giving government aid to such farmers as are willing to undertake the battle against tuberculosis in an intelligent way. This legislation should at all events offer free use of tuberculin under proper inspection to such farmers as are willing to adopt regulations which shall be devised by inspectors for the purpose of isolating the reacting animals.

Further suggestions in regard to legislation would be out of place here, but there is a task devolving upon the farmer and upon the legislator which must certainly be accomplished in the next few years. If our farmers do not wish their dairy industry to be menaced and perhaps ruined by the wider spreading of this serious disease it is time for them to become acquainted with the facts, and be ready to undertake the only practical method that has yet been suggested for getting rid of the disease, namely, isolation of all animals that show even the slightest taint of tuberculosis.

SOME PRACTICAL APPLICATIONS OF BACTERIOLOGY IN EUROPEAN DAIRYING.

BY H. W. CONN.

I. BACTERIOLOGY AND THE MILK SUPPLY IN EUROPEAN CITIES.

It is now about a dozen years since bacteriologists have turned especial attention to the subject of dairy bacteriology. During that time a large amount of information interesting to the scientist has been obtained, and this information has accumulated with especial rapidity in the last few years. Although the subject has been studied chiefly from a scientific standpoint, it is natural to expect that some facts have been discovered which might be put to practical use in dairying. This has been found to be the case, and in many respects the dairying industry has been very decidedly changed, if not almost completely revolutionized, by the application of facts which have been discovered in connection with dairy bacteriology. These changes have, of course, occurred somewhat rapidly. At the same time they have occurred in such an unpretentious way that most people hardly realize the extent to which dairy methods have been modified by facts discovered along these lines. The present paper will review certain aspects of the dairying industry in Europe for the purpose of illustrating how our modern methods have been influenced by dairy bacteriology.

CHIEF DISCOVERIES OF DAIRY BACTERIOLOGY.

The facts discovered in relation of bacteria to milk are very numerous, some of them having very highly important practical bearings and others having only scientific interest. In order to understand our subject more accurately it will be necessary, in the first place, to summarize the important facts which dairy bacteriology has disclosed, even though these facts may be familiar to everyone. The more important discoveries which have resulted from this line of study are as follows:

First, pure milk as secreted from the gland of the healthy animal, if kept free from external contamination, will not sour

or ferment, but may be kept indefinitely without any change taking place that is noticeable.

Second, all the ordinary changes which occur in milk after being drawn from the cow are due to the presence of bacteria in the milk. This includes not only the common souring, but all of the other changes which occur at intervals to trouble the dairymen.

Third, the bacteria which produce these changes are all secondary contaminations and do not belong to the milk as secreted from the gland provided the gland be healthy.

Fourth, the sources from which the bacteria that contaminate the milk are derived are several. At the head stands the cow herself. Bacteria lurk in the milk ducts. They adhere to the outside of the animal, clinging to the hairs, and, during the milking, find their way into the milk in great abundance. Next, the vessels in which the milk is drawn and in which it is kept are almost never clean, and contain bacteria in great numbers, ready to grow as soon as milk is placed in the vessel. Again, the dust of the air in the milking stall is a source of contamination. The extent of contamination from this source will vary widely and will be especially abundant when the milk stall is full of the dust from newly-disturbed hay. Lastly, the milker himself, his hands and his clothing, are sources of contamination.

Fifth, the action of the bacteria upon milk in producing undesirable changes is dependent upon temperature, for the bacteria in question grow slightly, if at all, at temperatures near freezing, and grow rapidly at warmer temperatures.

A second series of facts of perhaps even greater importance has been discovered in connection with the study of milk as a distributor of disease. The past ten years has shown beyond peradventure that milk is a prolific means by which certain diseases are distributed in man. We have learned that milk is, at the same time man's *best* food as determined by its chemistry and by its ease of digestion and assimilation, and the *most dangerous* food, from the fact that when improperly handled it may be the means of distributing disease to mankind.

The diseases which we have learned in these few years are distributed by milk are, however, not numerous. They are as follows: Tuberculosis, which comes directly from animals suffering from the disease and may be under special circumstances transmitted to man; diphtheria and scarlet fever,

two diseases which apparently also attack the cow and may be transmitted from the cow to man by means of milk. In regard to these two diseases, however, it must be stated that it is not as yet positive that they can be transmitted to man from a cow suffering from the diseases, although the evidence in our possession at the present time looks in that direction. Certain it is, however, that the milk may become contaminated from some secondary source with the germs of these diseases, and then the disease be transmitted to man.

Typhoid fever and cholera and a variety of diarrhœal diseases especially common in children are also transmitted by means of milk. In these cases, however, it appears that the contamination with the bacteria is always secondary. The cow herself does not suffer from these diseases, but bacteria from some source of contamination which get into the milk *after* it is drawn from the cow may be the cause of them. These are the important facts in briefest outline, which have been determined in connection with dairy bacteriology and which have led to very great changes in dairy methods.

APPLICATIONS OF SOME OF THESE FACTS.

It is, of course, impossible to enumerate all of the minor changes in dairy management which have been produced in dairying through all civilized communities by knowledge of the facts above mentioned. The treatment of the cow, and the treatment of the milk from the very beginning to the time it is consumed by man, are modified in countless little details in accordance with the facts that are known. The general change that has been introduced is quite comprehensively expressed by the statement that dairy methods have been so altered in the last ten years that the milk from a time immediately preceding the milking to the time when it is delivered to the consumer is carefully guarded against contamination. Farmers in civilized communities have learned the chance and the danger of such contamination, and they have therefore been slowly but effectually adopting methods of protecting the milk.

This occurs in the first place in the stable. Recognizing that the cow is one of the chief sources of trouble, attention is given to her. She is kept cleaner than was thought necessary a few years ago. Her udder is in many cases washed with warm water; the teats may be moistened before milking, or

perhaps washed with a disinfectant solution, which although of course not a very common procedure, does occur in many dairies where especial care is taken. In the better class of dairies it is thought as necessary to keep the cow carefully cleaned as it is to care for the horse, and the old condition of filth in which the animals were allowed to live is being improved.

The bedding which the animals use has been also more or less changed in view of the facts that have been discovered. Bacteriologists have shown that many of the most perplexing difficulties which the dairyman encounters in the keeping properties of his milk may be traced directly to the bedding. Instances of slimy milk and bitter milk which have troubled dairymen for a long time have been traced to the fact that the bedding used by the animals is infected with a certain malign species of bacteria, and that a change of bedding produces a mitigation of the evil at once. This of course gives the farmer a new vantage ground from which he can deal with troublesome affections in his dairy.

It has been shown abundantly that a second serious source of trouble in dairy processes is in connection with the manure, for from this source many of the most troublesome kinds of bacteria are derived, which, finding their way into the milk, give rise to the most mischievous effects and produce the greatest amount of irritation to the dairyman. In short, our more intelligent dairymen have learned that in the cow stall strict cleanliness is a necessity for successful dairying.

Very great change has been effected in the treatment of the milk vessels by means of bacteriological discoveries. In the first place, it is slowly becoming realized by dairymen that ordinary washing, or washing with soda, or washing with boiling water, does *not* serve to clean the milk vessels, and that after any such treatment, which was always regarded as sufficient a few years ago, bacteria will be left in the milk vessels in great quantity, ready to produce trouble as soon as the milk is placed therein. As a result, new methods of washing vessels have been introduced, most of which depend upon a treatment with superheated steam, which produces heat sufficient to destroy at least a large portion of the bacteria in the vessels.

One of the most striking changes in this respect which we notice to-day is the very rapidly growing tendency of distributing milk from the central supply not in cans from which it is to ladled out to the individual customer, but in glass

bottles, which are owned by the dealer, which are washed and sterilized by him, and which are filled and sealed in the central milk-distributing station. The advantages of this method are very great and its expense is apparently so slight that it is being adopted more and more widely by the milk supply companies. The bottles in question can be much more carefully washed in the factory than in the homes of the consumer, since they can be thoroughly sterilized by heat with very little trouble, and the milk which is placed in such bottles and sealed at the factory is certain to have the best possible chance of keeping. When the dairyman is obliged to depend upon the thoroughness of the washing of the milk vessels on the part of the consumer, he has learned by experience that great trouble arises from the lack of care in the individual houses. A large part of this source of trouble is removed by the use of glass bottles sealed by the dealer, and for this reason, if for no other, the use of such a method of distributing milk is rapidly extending. It is claimed by some companies that the expense is actually less than the older method of distributing milk. The milk can be bottled mechanically in the factory by a grade of help that can be obtained at wages considerably less than must be paid to employes who are obliged to travel with the distributing cart and measure out the milk to each customer, and, after being thus bottled, the distribution can again be carried out more rapidly and with a cheaper grade of help than in the older method. The saving of expense in this way is nearly enough to compensate for the cost of the bottles and their sterilization and the breakage which occurs in the process. Judging from the tendency of dairying at the present day, this method of handling milk is sure to increase and perhaps become almost universal in the course of time.

The fact that a considerable portion of the contaminating bacteria which produce troublesome changes in milk comes from dirt of various kinds which get into the milk during or after the milking, has led to the quite general adoption of new and more careful methods of cleaning the milk. This is done in some places by simply filtering through sand, large filters being used made of alternate layers of carefully cleaned angular grains of sand and cotton, and through these the milk passes with considerable rapidity. During its passage all of the particles of dirt of any considerable size are removed, and the keeping properties of the milk are quite noticeably increased. Such filtering does not indeed remove the bacteria

from milk. Bacteria are so small that no method of filtering has been, or probably can be, devised which can remove them and not also remove the fat particles from the milk. Such a filtering only removes the larger particles of dirt, but this is itself useful. In other cases the cleaning is produced by centrifugal force, the milk being passed through a special machine, which is something of the same nature as the separator, but in which the revolutions are less rapid and not sufficient to separate the cream from the milk, but are sufficient to separate all of the heavier particles of filth. Such a cleaning by filtration or by centrifugal force is of decided value to the purity of the milk, and the better milk companies in European cities are adopting the one or the other of these two methods.

An incidental result has been in the adoption of cement floors in most of the better establishments that have to do with the distribution of milk. The old style of wooden floors has been found to become so thoroughly impregnated with bacteria and so impossible to clean that they have been quite generally abandoned. Indeed, in some cities there is a police regulation that milk shall not be allowed to stand for any length of time in rooms with wooden floors. As a result, the use of cement flooring is rapidly extending and has been almost universally adopted. This change may be beyond question traced largely to the knowledge of bacteriology.

It has of course long been known that in order to keep milk it must be kept cold. Nevertheless, some of the facts discovered in this connection in recent years have been of practical value. It has been learned that the bacteria grow most readily, as a rule, at temperatures near that of the body of the cow and, therefore, when the milk is drawn from the cow it is at a temperature at which the bacteria grow most vigorously. As a result of this fact there has been introduced, almost universally, the method of cooling the milk to as low a temperature as possible *immediately* after it is drawn from the cow. For accomplishing this, a considerable variety of forms of apparatus have been invented in the form of milk coolers which use either cold water or ice, and through which the milk is allowed to pass at once after being drawn from the cow. The advantage of this cooling is very great indeed, and it has made possible the extension of the milk industry in places and under circumstances that would have been impossible otherwise. In European dairies this matter is of even more importance than in American dairying. One of the most striking differences

between dairying in Europe and in America is the slight use of ice in the European dairies. The milk which is brought into the cities is almost never cooled with ice. Even in the northern countries like Denmark, where ice might be supposed to be at least as easily obtained as in New England, we find that the use of ice is comparatively slight, and the milk which is brought into the cities is not brought in upon ice cars, but is hurried in as quickly as possible without any attempt at artificial cooling. Under these conditions, of course it is clear that the value of the original cooling of milk to as low a temperature as possible with cold water is a very great one. It is the one universal means of cooling milk now adopted in Europe.

MILK AS A DISEASE DISTRIBUTOR.

Leaving, now, such miscellaneous effects we notice the changes which the knowledge of milk as a distributor of disease has produced in dairy methods. The first fact which comes to our notice is that there is everywhere an endeavor made to exclude from the herd which supplies public milk every animal with any trace of udder disease, no matter what that udder disease may be. It has been shown conclusively that udder diseases are always sources of danger to one who drinks the milk. Sometimes these troubles are of tuberculous nature, and then there is danger of tuberculosis. More commonly, however, the udder troubles are not tuberculous. But the bacteria which get into the milk from a simple inflamed udder are frequently those which cause intestinal troubles in children and in adults. Evidence is abundant and satisfactory which shows that diarrhœal troubles in mankind are in many cases to be traced to bacteria that come from various kinds of diseased udders. For these reasons it is recognized everywhere that *all* animals with udder diseases should be separated from the dairy-supplying herd. It is of course not pretended that such a result is accomplished in European herds. It is an extremely difficult matter to exercise a control upon the herds of the individual farmer, but the attempt is being made by distributing information and by police regulations to accomplish the result as thoroughly as possible.

A second result has been in teaching the health authorities that there is great danger to the public health in allowing milk

to be handled by any person suffering from or even recovering from one of the contagious diseases above mentioned. Positive evidence has been found of epidemics of diphtheria, and probably, also, scarlet fever, produced by the handling of milk by a person who was just recovering from these diseases. In consequence, the best milk companies try to prevent any persons who are suffering or recovering from typhoid fever or scarlet fever, or other contagious diseases, from having anything to do with the handling of the milk. The milk is thus guarded far more carefully than it was in earlier years. It is not only prevented from coming in contact with such suspicious attendants, but it is even prevented from coming into the vicinity of such patients. Here again it must be admitted that the attempt to guard against contamination by disease germs is as yet only a partial success. The difficulty of controlling the methods on individual farms is well nigh insurmountable, but the better milk supply companies have the rule that as soon as a contagious disease appears upon any farm, the milk from that farm shall no longer be received by the milk company until the local health board have pronounced that the conditions adopted on the farm are perfectly satisfactory and safe.

With this same purpose in view, more attention has been paid in recent years to the water which is used on the farm for washing the milk vessels. The well known fact that the typhoid fever germ may live in and is frequently distributed by water, and especially by well water, has led to the conclusion that many an epidemic of typhoid fever has been produced by the fact that improper water has been used in washing the milk cans. Indeed, several epidemics of typhoid fever have been traced to such causes. Therefore, more care is being taken each year in scrutinizing the source of the water which is to be used by the dairymen. In some cities the milk companies actually make a chemical analysis of the water upon the farm before they will admit a farmer among its patrons. When a farmer desires to sell milk to these companies, the companies send inspectors who examine his farm as to its sanitary condition, and end by making an analysis of the water, and if the analysis shows the water to be impure they either insist that the farmer shall obtain a better supply, or refuse to accept his milk.

MILK SUPPLY INSTITUTIONS.

These various applications of our knowledge of dairy bacteriology to dairying, so far as concerns the general milk supply, are, at the present time, made chiefly either through the public inspector or by the formation of large milk supply companies. The supply companies are indeed more successful than the official inspectors. It is easy to understand that such companies can control the matter very much more easily than can any public authorities. Public law may make the rule that a cow with an udder disease shall not furnish milk to the public, but the individual farmer with little to hinder him can break the rule almost at will. When, however, a milk supply company makes such a rule and keeps inspectors frequently visiting the farms, the farmer knows that if he breaks the rule he will probably be discovered and lose the market for his milk. He is therefore very much more likely to follow the instructions given than when they come through public statute. The milk supply companies of the various cities in Europe are therefore adopting regulations of this sort more and more carefully each year, and as a result the character and quality of the milk furnished by these companies is improving each year. There is hardly a city of any size in Europe that does not have one or more of these large companies which furnish milk in large amount and whose milk has acquired an established reputation.

Probably the most noted of these milk establishments is one in Berlin, known as that of C. Bolle. The organization and the management of this establishment is unique. It is a large establishment, collecting and distributing about 70,000 quarts of milk daily. This means a much larger patronage than it would mean in an American city, for the people in Berlin drink comparatively little milk, and the 70,000 quarts of milk mean nearly 300,000 patrons. The establishment of C. Bolle consists of a large number of fine buildings in the midst of the city. As one visits the institution he is especially struck, not so much with the methods of handling milk as with the methods of handling men. Perhaps the first room that he enters is a large hall, where there is held weekly a religious service and where there are occasionally given fairs and entertainments of various kinds by the employes of the establishment. He learns presently that there is a school connected with the establishment, where the children of the em-

ployes obtain excellent education. He learns that a well equipped and carefully conducted kindergarten is found inside of its walls. He is taken into a room where he finds 200 or 300 children attending a singing school which is held once or twice a week. He learns that the establishment has its own system of insuring its employes in such a way that by the setting aside of a small portion of the wages weekly the employes are insured against accident and sickness, and the family insured against his death. His family is thus cared for, and poverty among the employes is prevented. He finds a well equipped library and learns that there is a branch of the Y. M. C. A. organization doing work among the men, and a somewhat similar organization doing work among the women. He learns that there is a weekly paper printed in the establishment, that a Sunday-school is carried on each week; and he even finds that the company furnishes and repairs the boots of its employes. In short, he finds inside of this establishment almost what might be called a large family of people joined together for mutual good and for mutual improvement. It is not to be wondered that the employes are extremely proud of being members of the Bolle establishment, and that the places are at a very great premium. With such an intelligent, well-cared-for lot of employes it is possible to handle the great business with ease and accuracy, and not to experience the troubles which so frequently come elsewhere from carelessness or ignorance.

So far as I am aware there are no other institutions in European cities that compare with the one described, in the extent of the organization among its employes. At the same time there are large numbers of companies in different cities whose purposes are similar to those of Bolle, namely, to furnish in large quantities a supply of the very best kind of milk to citizens of larger communities. Such institutions soon obtain a reputation which is their stock in trade. They cherish it with a great deal of care, and every attempt that appears possible is made to protect the quality of the milk which they furnish their patrons. Their methods effect every condition which may surround the milk from the very outset. In the first place, a careful selection is made in regard to the dairyman who shall furnish the milk originally. The cows are, as a rule, examined by a veterinarian before the milk is accepted by these institutions. The sanitary conditions in the dairy are looked into carefully, and suggestions for improve-

ments made. From time to time an inspection by paid officials is made in all of the dairies which furnish the milk. The institution of Bolle spends $15,000 a year in official inspection among the dairies of its patrons.

The milk is carefully tested, both chemically and as to temperature, when it reaches the distributing factory in the city. In some cases every can of milk brought in is *tasted* by experts to determine whether there is any trouble appreciable to the tongue. The milk is commonly filtered or run through a centrifugal machine, and large quantities of milk derived from a great variety of sources are thoroughly mixed together in order to insure an almost absolutely uniform product. The greatest care is taken in sterilizing the bottles in which the milk is distributed, or the milk cans in which it is stored.

If a contagious disease occurs on a farm, the attempt is made to stop the reception of milk from the farm in question for a length of time which appears to be necessary. Some of the companies even go so far as to pay the farmer for the milk during the whole of the time in which the milk is refused at the factory because of such infectious disease, a kindness which is sometimes abused by the farmer. If an infectious disease should appear in the family of one of the employes of such an institution, the individuals of the family are not allowed to have anything more to do with the handling of the milk until complete recovery takes place. In some cases this attempt to prevent distribution of contagious diseases goes so far that if an infectious disease occurs in the family of one of the consumers of the milk, the milk is no longer delivered to the family in question from the ordinary milk-distributing cart, but a special messenger is sent from the factory to such houses, the belief being that by such means any possible danger of distributing the disease from house to house is prevented.

Most of these institutions have chemical laboratories, and some of them have bacteriological laboratories, where the character of the milk is studied and where the infectiousness of the milk, so far as its effect upon animals is concerned, can be investigated. In some of them, careful observations are being made to determine whether their milk is the cause of the distribution of tuberculosis. Up to the present time, so far as I am aware, no attempt is made to use tuberculin among the cattle for the purpose of excluding from the milk supply such animals as may react to this test.

Nearly all of these institutions make a special attempt to furnish milk of extra character for the use of young children. This is done not only by securing especially healthful cows, but also by feeding them upon what is regarded as especially healthful food, and the milk thus obtained is, either rightly or wrongly, regarded as safer for the use of children than the ordinary milk, and it naturally is sold at a greater price.

It is of course clear that the development of methods by such large institutions are sure to produce a gradual improvement in the quality of the milk. This improvement has also been stimulated by the gradual development of police regulations in the various cities. In Germany, in particular, the rules for the inspection of the ordinary milk supply have been perfected in the last dozen years, until now they are extremely rigid. The inspection of milk here is wholly in the hands of the police, and thousands of tests are made monthly of the ordinary milk distributed through the streets of Berlin. At the institution of C. Bolle the test is made before the milk-distributing carts leave the supply station, and then the carts are locked so that the milk cannot be tampered with. These tests, it is true, are mostly chemical and physical, rarely bacteriological, but the result has been that the application of the tests have little by little raised the quality of the milk from a bacteriological, as well as a chemical, standpoint, and it is found that to-day the milk supplied in these cities has a very decidedly smaller average number of bacteria than the milk supplied a few years ago, as well as a better average chemical analysis. All of these changes in the quality of the milk have been in the way of an improvement, and, if we except the fact that the milk used to-day probably is more likely to be contaminated with tubercle bacilli than it was ten years ago, we may state that the advances made in the last decade, as the direct result of the application of the bacteriological knowledge, have produced a gradual but a very decided improvement in the quality of the milk in the cities in Europe.

MILK STERILIZATION AND PASTEURIZATION.

Probably the most important change that has come over the system of dairying as the result of bacteriological knowledge has been in connection with processes of sterilization and pasteurization. The extension of the belief that milk is the cause of various contagious diseases, as well as a considerable

portion of the diarrhœal diseases among children, has led to the custom of sterilizing milk for the purpose of killing all bacteria that may be present. Sterilizing or boiling milk was first adopted in cases of sickness, since it was found that boiled milk was more advantageous to the patient than raw milk. Its use extended to the diet of children, and in recent years more and more widely among adults, until in some places the practice of sterilizing milk for consumption is well nigh universal. In Germany it is very common. In Switzerland, well nigh universal in cities. In England it is hardly more common than in the United States. The purpose of such treatment is manifestly two-fold. It is primarily to destroy all disease germs and thus render the milk harmless from the standpoint of infection. It is, secondly, to produce a grade of milk which will keep longer than without such sterilization. The rare use of ice in Europe makes this second advantage of sterilization a more important one than with us.

As the popularity of sterilized milk has been increasing in the last ten years, naturally there has developed a greater knowledge of methods and a perfection of machinery for accomplishing the purpose. We find that the methods have differentiated themselves in three different directions, according to the amount of temperature used in bringing about the result. The first produces absolute sterilization, which kills every living bacterium that may be present in the milk. The second produces an almost complete sterilization, such as is obtained by simple boiling, while the third abandons the idea of killing all bacteria, and only endeavors to destroy the disease germs and a majority of the others. In connection with these three methods there have been invented many machines of more or less value. It is not the purpose of this article to attempt to describe these machines, although their manufacture has become a great industry in itself, and in some countries they have almost revolutionized the matter of milk distribution in cities. It is, however, necessary to refer briefly to the two extreme processes above mentioned, viz.: the complete *sterilization* and the process known as *pasteurization*.

Sterilization. — The complete sterilization consists in heating the milk to a temperature somewhat above that of boiling water, the actual temperature adopted varying slightly from about 215° (102° C.) to 221° (105° C.), or 223° (106° C.), and

the time of heating also varying quite widely. The machines devised usually receive a large number of bottles of milk, heat them to this temperature, and then close them, sealing them hermetically, while they are still inside of the apparatus, in order to avoid the chance of air contamination if the machine were opened before the sealing of the flasks takes place. Various mechanical contrivances for this purpose have been devised. Such milk is then sold as sterile and sure to contain no bacteria, and as, consequently, capable of being preserved for an indefinite length of time. Such milk may be exported, may be kept for months, and whenever it is opened it will be as fresh as the first day it is closed. The popularity of this type of sterilized milk has undoubtedly been growing quite rapidly in the few years since it has been offered to the public. People who are aware of the dangers from drinking milk are glad to be able to relieve their mind from the conception of the danger by feeling that they are drinking milk that is absolutely safe.

The results of the extension of the use of such sterilized milk are, according to the claims of the statisticians, very satisfactory. It has been found that, as the use of sterilized milk has extended, the number of deaths among children from intestinal troubles has decreased. This decrease, moreover, is undoubtedly to be traced to the milk sterilization, as is shown by a careful comparison of the amount of mortality among children living upon sterilized milk and those living upon raw milk. The following statistics will indicate this and show to what an extent the adoption of sterilization in milk is having an effect upon infant mortality. Out of each one thousand deaths that occurred in the city of Grenoble, France, in the years 1894-1897, there occurred the following number among infants:

In the year	1894	1895	1896	1897
Among children using raw milk	66	86	54	69
Among children using sterilized milk	25	42	16	27

Wherever the adoption of sterilization has occurred a somewhat similar result has been reached.

There are, however, certain disadvantages in this method of treating milk, disadvantages so great as to lead a large class of people to refuse absolutely to adopt sterilization. Firstly, the treatment of milk by such a high temperature very decidedly changes its taste and gives it the well known cooked taste, which to many people is quite disagreeable. Many

people say that they prefer to drink no milk rather than to drink milk that has been thus treated. Moreover, not infrequently the appearance of the milk is changed from a white to a brownish color, and this adds to the hesitation with which many people drink such milk. These are doubtless minor matters, since one's taste could be modified if the practice should become necessary.

Secondly, it is found that even with the very best of methods the sterilization is not absolutely sure. It is true that in the vast majority of specimens thus treated the milk is sterile and may be kept for an indefinite length of time. It is true, also, that in all cases the true disease germs are destroyed by this temperature. But it is also true that in a small number of cases the milk thus treated still retains certain bacteria spores which subsequently grow in the milk and produce very decided effects upon it so that the milk does not keep for the length of time expected. The serious matter in this connection is that the changes that are produced in the milk by these resisting germs are, as a rule, such as do not appeal to the eye, and perhaps not to the taste, so that the milk may be full of bacteria and may have its chemical character quite decidedly changed and yet be swallowed freely with the belief that it is perfectly normal. Now, while these resisting germs are not true disease germs, there are among them some which produce certain poisonous products giving rise to intestinal troubles, and it sometimes happens, therefore, or at least this is the belief of some bacteriologists, that the so-called sterilized milk may, in spite of the high heat, give rise to intestinal troubles among children that are fed upon it. The serious factor in this matter is that the eye and the taste detect no difference between such milk and milk that is absolutely sterilized.

Lastly, it appears to be pretty generally believed that milk that has been thus sterilized at high heat is somewhat less digestible and less easily assimilated than raw milk. Over this matter there has been and is still considerable dispute, but probably the balance of evidence indicates that there is a slight inferiority in the value of such milk as food.

These objections have led to the dislike of sterilized milk on the part of many, and to the adoption of the method of *pasteurization* which is at the present time gaining a firm foothold in certain localities.

Pasteurization. — Pasteurization consists in heating the milk to a temperature of about 165° or 175° (74° or 80° C.) for a short time, and then rapidly cooling it. It does not pretend to destroy the bacteria in the milk, but it does destroy, or at least renders innocuous, all of the true disease germs, and it reduces the number of bacteria very greatly. The reduction in the number of bacteria is so marked that the milk thus treated can be kept sweet for one or two days longer than milk that has not been thus treated. The advantages claimed for pasteurization are that it destroys the disease germs without producing the unpleasant taste and without producing any effect upon the milk which lowers its digestibility. Moreover, it is known by the consumer that the milk is not designed for indefinite keeping, and that it must be used fresh. It will therefore always be consumed before there has been a chance for the great development of poisonous products, which occasionally occurs in the bottles of sterilized milk which have been kept for weeks. In other words, all of the advantages for quick consumption which are obtained by sterilization are obtained by pasteurization and in addition it has advantages of its own. The fact that it does not produce a complete sterilization condemns it in the minds of most Germans, who want to do everything thoroughly if they do it at all. To those who are after practical rather than absolute results, however, the method has much to recommend it.

Pasteurization has therefore become somewhat popular in recent years. For several years the method has been used quite widely in private practice. The milk that is given to children, or milk that is used for drinking, is frequently heated to a moderate temperature and subsequently cooled. There have been invented, both in Europe and in this country, special forms of apparatus which are designed for producing this result with ease and accuracy.

In very recent times there have been developed in the large milk supply institutions methods which are designed for furnishing such pasteurized milk on a large scale. Beyond question the most highly developed of these is one in the city of Copenhagen. In this city there is one large institution which furnishes pasteurized milk to its customers in great quantities. At the present time the amount of milk thus distributed in the city is about 30,000 quarts per day, an amount equal to that of any of the other establishments in the city which furnish raw milk.

The methods adopted in this institution are unique, inasmuch as they have been developed wholly in Copenhagen, and indeed inside of the walls of this establishment. The milk, after being received, is subjected to a chemical analysis, but less attention is paid to the temperature of the milk than in the other institutions. Less attention is paid also to the matter of infectious diseases than in other institutions, it being assumed that isolated cases of infectious disease will have no influence upon the health of the people who drink the milk, since it is to be subsequently pasteurized. If there should be a widespread epidemic among the farmers, the matter would be taken into consideration, but it is not thought necessary to consider isolated cases. The milk, after being weighed, is passed through a very complicated and extremely ingenious machine which has been devised upon the premises. The description of this machine cannot be given here, but the milk passes through it in a constant stream, and during the passage it is heated to a temperature of 175° (80° C.), kept at that temperature for a moment, and is then cooled rapidly to a low temperature, and when it leaves the apparatus it is quite cool. It is then run rapidly into carefully sterilized bottles, sealed at once, and stamped with the company's stamp, and is distributed over the city in ordinary milk carts. In this institution the greatest care is taken in washing and in sterilizing the bottles, the bottles used for this purpose being not simply sterilized by steam, as in most institutions, but in an enormous iron chamber which is hermetically sealed and in which steam is introduced at a high pressure, so as to produce a very high temperature. Any surplus milk which the company receives is passed through a separator and the cream used for making butter, the rest being sold as skim-milk. The institution has a chemical and a bacteriological laboratory that keeps a careful watch of the efficiency of the pasteurizing apparatus. The whole success of this institution is in the ingenuity of the pasteurizing apparatus, which is capable of pasteurizing milk at the rate of about 2,000 quarts per hour, and can run continuously without trouble. It has been objected that such machines which run continuously and only heat the milk to 175° (80° C.) for a moment do not do their work thoroughly. This objection depends entirely upon the object in view. If the design is to destroy the bacteria wholly, or in large measure, the objection is well grounded. But if the object is simply to remove the dangers of distributing disease by

means of the food supply, the machine accomplishes its purpose, for a heat of 175° (80° C.) continued a minute probably renders innocuous all the disease germs likely to be in milk.

The surprising fact is that this Denmark company is able to furnish its milk to its customers at the same price that the ordinary companies in the city furnish raw milk and can do this at a profit probably equal to that of the other companies. The explanation appears to be in several circumstances, the chief of which is that they do not need to demand that the milk which is sent to them shall be kept so cool. It is cheaper to produce heat than to produce cold, and whereas the ordinary milk dealers in Copenhagen insist that the milk which they receive shall not be at a temperature of above 39° (4° C.), the pasteurizing institution receives it up to 50° (10° C.). The difference in expense between keeping the milk at 39° (4° C.) and 50° (10° C.) is almost sufficient to pay for the expense of pasteurizing milk after it reaches the factory. Heat is cheaper than cold. There are other lines in which a saving is produced, also, and the result is that pasteurized milk can be bought in Copenhagen at the same price as ordinary milk. The purchaser can be confident that he is obtaining milk which offers no danger, either as a source of tuberculosis or any other contagious disease, which has no taste other than that present in normal milk, and which is as digestible and as easily assimilated as raw milk. It is the most successful application of pasteurizing on a large scale that has been adopted anywhere in the world, and furnishes the public with this food product in the safest and the most satisfactory condition.

So far as I am aware, the method of furnishing pasteurized milk in large quantities has not been adopted to any great extent in other European cities. There are some other places where smaller institutions have been developed and where such pasteurized milk can be bought, but as a rule the purchasers in European cities must buy either raw milk or sterilized milk.

This whole development of pasteurized and sterilized milk is apparently in its infancy. The belief that milk is frequently a source of the distribution of disease is so rapidly growing that the demand for some method of treating milk before its distribution is becoming louder each year. In some European countries children in the schools are taught the danger of drinking raw milk. The physicians from the medical schools are everywhere taught of this danger and, as the result of these

two facts, the demand for sterilization and pasteurization is absolutely sure to grow in the future. It might be well for our own dairymen in the United States to take a lesson from these facts and to be prepared in the near future to furnish our own public with a similar grade of pasteurized and sterilized milk. For it is pretty certain that a similar demand is to arise in this country. If some of our milk companies would establish as successful a method of pasteurizing milk as has been adopted in Copenhagen, and should use the proper means of introducing it into our cities, there is no question that the scheme would meet with very great success and would undoubtedly yield large financial returns to its originators. Although the people of this country are not so alarmed over the dangers from milk as are the Europeans, nevertheless we drink much more milk than they do in Europe, and if the consumers of milk could be promised absolute surety against disease, and at the same time be furnished milk at the same price as the ordinary milk, there is no question that the method would be exceedingly popular from the very start.

II. BACTERIOLOGY IN BUTTER-MAKING IN EUROPEAN DAIRIES.

The influence of bacteriology upon methods of butter-making has not been so widely extended as has its influence upon matters connected with milk supply. If we look over the various countries in Europe we shall find that the southern Continental nations and England have, up to the present time, been almost unaffected in their methods of butter-making by the facts connected with the discoveries of bacteriology. On the other hand, the northern nations have been more influenced thereby, and in northern Germany, and more especially in Denmark, the methods of butter-making have been almost completely changed within the last ten years under the influence of bacteriological discoveries. In the butter-making communities in northern Europe, the whole process of handling the milk from the time that it leaves the cow until the time the butter is ready for market has been entirely revolutionized. The methods adopted there are only somewhat slowly extending into other countries, but apparently it is a matter of a few years only when similar methods will be adopted everywhere that there is an attempt made to obtain a high quality of butter.

As is well known, the study of bacteriology has turned the attention of butter-makers primarily to the process of cream ripening. It has shown them that in the proper ripening of the cream lies the secret of obtaining the best quality of butter. It has shown them that under usual conditions this cream ripening is largely a matter of chance. It has proved that the quality of the product is in considerable degree dependent upon the particular kind of bacteria which may ripen the cream, and has shown that by natural processes the butter-maker is unable to be sure of obtaining the desirable species. These facts are well known, but the practical application of them has not been very widely extended in any European country except Denmark and northern Germany.

PURE CULTURES IN DENMARK.

It was in Denmark, however, that the practical application of this subject was first made. The reputation of Danish butter is well known. It stands, without question, at the head of all types of European butter. Danish butter is exported in very large quantities, is sold at the highest prices in foreign markets. This reputation has always adhered to the butter of Denmark, and within the last ten years, since the application of bacteriological methods of butter-making, the reputation of the butter has not fallen, but has increased.

It was in Denmark that the first attempt was made to use what are now known as pure cultures for cream ripening. Under the influence of the Danish bacteriologist, Prof. Storch, there was introduced into the Danish creameries a method of ripening cream through the agency of artificial bacteria cultures. The method was moderately successful and gradually extended. From Denmark it was adopted in the dairying countries in northern Germany, and from these places it has in isolated instances extended to other countries. But even to the present day it is only in these two countries where the use of this method has been adopted in anything more than exceptional instances. In other countries, pure cultures are used only when the butter-maker has trouble with his butter. In Denmark, however, the use of pure cultures has become very common. It is stated that *over 95 per cent.* of the butter made in this great butter-making country at the present time is made by the agency of artificial cultures used in cream ripening. This percentage is surprising, and conveys a very great

lesson. Danish butter-makers stand at the head of the profession for the world. Danish butter commands the highest price and has the highest reputation of all butters. The Danes themselves adopt with practical uniformity the use of pure cultures, and the undoubted inference to be drawn from this is that the use of pure cultures in cream ripening is not only practical, but it results in uniform advantage.

The pure cultures that are used in the different dairies in Denmark, however, are not all alike. There are several of them for sale in dairy districts, and different cultures contain quite different species of bacteria. Most of them are really pure cultures, that is, masses of a single species of bacteria. Some of them, however, are mixtures of different bacteria, and one at least contains no less than ten or a dozen different species of bacteria mixed together. Such a mixture is not an artificial one, but is obtained simply from some natural starter. Doubtless in the action of such a mixture some of the bacteria have no influence at all in the process of cream ripening.

The actual operations in the Danish creamery may be interesting to describe in some detail, inasmuch as they illustrate so well how all of the lessons from bacteriology are brought together and applied. A typical Danish creamery, then, may be described somewhat as follows: The milk is brought to the creamery in large cans. As soon as it reaches the creamery it is placed in a large receiving vessel and warmed to a moderate temperature, about 25° C. From this receiving vessel it passes directly into a separator, and the skim-milk and the cream are received in separate compartments. The skim-milk is immediately pumped from the receiving vessel into a large receptacle surrounded by steam coils, through which steam is passing constantly. In this receptacle the skim-milk is heated to a temperature of 175° (80° C.), the milk in the receptacle being kept constantly at this temperature. As it is being constantly pumped in it is also being constantly drawn out into the milk cans of the farmer, who takes this heated milk and carries it back to his farm for use in feeding calves and pigs. The skim-milk is in this way pasteurized for the purpose of neutralizing the danger of distributing tuberculosis.

The cream which comes from the separator is elevated by mechanical contrivances into a smaller receptacle, which is also surrounded by steam coils, and in this receptacle the cream is also heated to a temperature of about 175° (80° C.),

or somewhat less, remaining at this temperature for a short time. This pasteurizing not only destroys the tubercle bacilli and all other disease germs which might be distributed through the butter, but it also destroys the majority of the lactic bacteria. After the pasteurization the cream is cooled and received in large ripening vats.

In the meantime the dairyman has prepared his starter. This is prepared in milk that has been sterilized by high heat, and which has been inoculated with a sufficient quantity of the commercial pure culture, which the dairyman buys in small quantities at short intervals. The milk thus inoculated is allowed to stand at a warm temperature for a day or more, until it becomes properly acid and slightly curdled, and this starter is added to the pasteurized cream after it has been cooled. The rest of the process is not especially different from that in other dairies. The ripening continues about a day and the churning and working are as usual, although the Danish butter-maker is more frequently inclined to use his hands in working the butter rather than a mechanical butter-worker. The butter may or may not be salted, but if it is salted the amount of salt is extremely slight, not a quarter as much as is used in the ordinary creamery in our own communities. By this method it will be seen that pasteurization has extended almost universally in Denmark, not only to the skim-milk, but also to the cream. As a result, there is an equally wide use of artificial starters. The details of the process in different creameries, of course, differ. In some, the whole milk is pasteurized before it is run through the separator instead of after. But in practically all, the process of pasteurization is an integral part of the butter-making.

The results of this method of the use of pure cultures in Denmark are, of course, satisfactory or the method would not be so universally used. It is somewhat more expensive than to make the butter without the use of pasteurization and pure cultures, and we may be sure that if the results were not satisfactory the process would not have been adopted in over ninety-five per cent. of the creameries.

DANISH DAIRYMAN'S ASSOCIATION.

The Danes have a somewhat curious association of butter-makers, designed for aiding the butter-making communities and determining so far as possible the best methods and the

results of methods. This association comprises some 700 of the largest creameries in Denmark, and it is supported by government appropriation of about $8,000 yearly. At Copenhagen there is a central committee whose duty it is to put into operation the practical details of testing butter. At short intervals this committee sends word to a number of the creameries to forward to Copenhagen immediately a sample tub of butter from their creamery. There is no regular order taken in choosing the creameries, and the butter-makers have no previous notice as to when they are to be called to send butter. As a result, there is no possibility that a creamery can prepare a special lot of butter for this exhibit. This butter is brought to Copenhagen, placed in a cold room in specially prepared vessels in such a way that it is impossible for the scorer to determine the mark on the butter and therefore to determine from what creamery it comes. Apprizers score the butter after it has stood in this cold room for a couple of days. Care is taken that not a large enough number of samples are sent at once to make the scoring too difficult. The apprizers in each case consist of six men drawn from a list of about forty butter exporters. Weekly records of the scoring are published by number only, each creamery thus knowing the scoring of its own butter, but not of its rivals. After the scoring has been made, the marks on the butter are examined and a record is kept of the scoring, together with all of the data in regard to the manufacture of each sample of butter. The data thus kept include everything in connection with the method of working, of salting, the use of pure cultures, and the particular kind of pure cultures that are used. By this method of testing butter this dairy association has been obtaining a large amount of valuable information as to the practical result of methods in use. They have here means of determining, not by isolated scoring, but by a long-continued series of observations, the value of pure culture methods as compared with methods without pure cultures, the value of the different brands of pure cultures, and all other details which may be collected.

From the record of this association it is therefore possible to determine with a considerable degree of accuracy what has been the actual result of the use of pure cultures in Denmark. Apparently the results are as follows: Butter made with pure cultures is almost always better than that made by the older method. While this is not always the case, and while it is true

that some samples of butter made without pure cultures rank very high, there is no uniformity in regard to the grade of the other types of butter, while the butter made by pure cultures is of a uniform high grade. There has been, since the introduction of pure cultures, a noticeable and an almost universal improvement in the grade of Danish butter in general. Whether this means that the best grade of Danish butter has been improved, it is not very easy to determine, but beyond question the butter in Denmark to-day grades higher and is of a superior quality to the butter of ten years ago, before the use of pure cultures was adopted. It has been found, thus far, difficult or impossible to determine any very great difference between the different kinds of pure cultures that have been used in the different creameries. At one time one of the brands of pure cultures will score higher and at another time another brand will score higher, a result thought to be due to different methods of use. With the fluctuating results that have been obtained hitherto, no one of the types of pure cultures stands so prominently ahead of the others as to claim any special merit.

While the grade of the butter has been uniformly increased it has thus become something of a question whether the keeping property of the butter has been improved or diminished. Most dealers say that the butter keeps as well as ever, but some of the English dealers insist that the butter in recent years deteriorates more quickly than it used to in earlier years. This is thought to be due to the fact that the general grade of butter sent from Denmark is at the outset higher than it was a few years ago, and, as is well known, the highest grade butter deteriorates more quickly under the best of circumstances than butter of an inferior quality. The lack of keeping power complained of by certain dealers is, according to the belief of the Danish experts, due rather to the uniformly high grade of the butter than to the fact that the butter actually deteriorates more rapidly than in earlier years.

The butter that is produced by means of these pure cultures is extremely uniform and there is very little difference between the flavor of the butter produced by the different brands of pure cultures. In general, one accustomed to American butter will find that the flavor of the Danish butter is rather flat. The taste of the European butter consumer demands something different from the taste of our own consumers. In Eng-

land and elsewhere in Europe there is desired a butter with the slightest possible flavor and with the smallest amount of salt, or, indeed, unsalted. Such butter would not meet the taste of our consumers. In the United States there is desired a butter with more flavor, and the butter which we are especially desirous of obtaining here conversely is thought by Europeans to be too strong and to savor too much of decay. These differences in the quality of the butter are simple matters of taste, but it is necessary for our American butter-makers, in comparing Danish methods with our own, to take into consideration the fact that the Danish butter-makers make a product somewhat different from our own, and one in which there is not so high a flavor.

BACTERIA IN OLEOMARGARINE.

Closely associated with the application of bacteriology to butter-making is its application to the preparation of artificial butter and various oleomargarine products. This subject, however, may be passed over with only a word. In certain European countries, especially in Holland, oleomargarine is made in very large quantities. The largest factories in the world are located in Rotterdam. In these factories the use of pure cultures has for some time been adopted with almost absolute uniformity. The shrewd business men who manage these factories have thoroughly learned that if they wish to obtain in their products a flavor imitating that of butter they are obliged to use bacteria to give them this flavor. They therefore buy the artificial pure cultures and inoculate them into large quantities of pasteurized milk in essentially the same way that the butter-maker inoculates them in his cream. They allow this milk to stand in a warm place for a length of time, which will produce the proper amount of souring, and then this ripened milk is mixed with the fats and the mixed oils made into margarine products. The result is that a flavor of butter which is, of course, derived from bacteriological products of the souring milk, is imparted to the margarine. All of the better grades of artificial butter are made in this way. The margarine factories use various kinds of pure cultures and experiment upon them with a good deal more care and know much more about their use than do the butter-makers. Butter-makers make comparatively small quantities of butter, while oleomargarine factories make their

product in very large quantities, and their market is much more dependent upon the grade of their product than is the market for butter. Some of these oleo factories have their own bacteriological laboratories, where experiments are going on constantly and where they can obtain their own pure cultures and make use of the very best results of the most recent advances in bacteriology. The wide application of bacteria in the manufacture of oleomargarine products should be a lesson to the butter-maker.

III. BACTERIOLOGY IN CHEESE-MAKING IN EUROPE.

During the last few years a considerable majority of the students of dairy bacteriology have turned their attention from the study of milk and butter to the study of cheese. The reason for this is a practical one. It has been recognized for some time that the character of the different varieties of cheese is due, at least in considerable degree, to the peculiar kinds of fermentation which take place in the cheese during the ripening. In the cheeses which are popular in the markets of Europe, the variety of flavor is very great. One who goes through the markets in the different countries of the Continent is especially struck with the extremely great differences between the different kinds of cheese, and the great number of varieties which are popular in different localities. If these differences are due to types of fermentation it would be plainly a matter of great practical value to dairying if there could be discovered some strictly scientific method of producing the different varieties. The bacteriologist who shall discover the means of applying in a practical way to cheese making the facts which have been discovered in connection with bacteriology will not only gain a great reputation for himself, but will undoubtedly reap a large amount of financial profit at the same time.

The problems connected with cheese offer, therefore, a very fertile field for research. In the application of bacteriology to butter-making it has been thought that perhaps no further great improvement can be made now that we have actually learned to control the flavor of butter, at least to a considerable degree, by the use of pure cultures. But in the operation of cheese-making there are almost limitless possibilities, because

of the many varieties which each country demands. If it were possible to find some means of making the popular cheeses in other localities than those where they are ordinarily made, it is plain that a great impetus could be given to dairying. If Edam cheeses could be manufactured equally well in all countries where they are in demand, if Swiss cheeses could be made with equal ease and equal surety outside of Switzerland, it is of course plain that the whole condition of the dairy industry would be changed. For these various reasons it is that in the last few years bacteriologists have ceased to pay much attention to the problem of the relation of bacteria to butter, and have given a correspondingly great amount of study to the problem of cheese-making.

The problem, however, has proved to be an extremely difficult one. Its very complexity has made the subject very difficult to reach. There is no question that the flavor of the cheese is developed during the period of ripening, which occurs after the cheese is made. But in that ripening there are a variety of changes that take place. The changes in the chemical nature of the cheese are very profound, and while these are in part due to bacteria they are apparently also in part due to certain unorganized ferments which are present in the milk. Moreover, the growth of bacteria in such cheeses is irregular and presents problems which have hitherto been largely insoluble. That the cheese flavor is due to bacteria or to moulds is everywhere agreed.

Bacteriologists are as yet unable to agree as to what kind of bacteria are most intimately concerned in the ripening process. While there are some who bring forward an abundance of evidence that the *lactic* organisms are those primarily concerned in the process of cheese ripening, there are others who bring forward also a large amount of good evidence that it is not the lactic organisms, but rather bacteria, which give rise to an alkaline reaction and which have power to digest proteids; while beyond doubt some types of cheese owe their peculiar character to moulds, rather than bacteria. It is of course clear that when such a simple, primary matter as this cannot be settled with any degree of unanimity, we cannot expect to find any very considerable amount of practical results arising from bacteriological work. Until a more thorough knowledge of the whole process is obtained we can expect to find very few practical applications of bacteriology in cheese-making.

At the same time, there have been some improvements which have taken place in cheese manufacture as the result of bacteriological knowledge. It has been shown beyond peradventure that a majority of the " faults " which arise in cheese and which make their appearance during ripening, are due to the growth in the cheese of certain malign kinds of bacteria, or sometimes due to the undue growth of bacteria which, under different conditions, would produce no injurious effect. The " faults " which arise in the cheese during the ripening are quite varied and need not be enumerated. They concern the appearance, the consistency, the taste, the odor, and the healthfulness of the cheese, and while it would be premature to say that they are all due to improper fermentations, it is now known beyond question that at least a majority of them may be attributed to such causes. Moreover it is known that in many cases the sources of such troublesome fermentations lie in the fact that there has been used in the manufacture of the cheese, milk which has become unduly contaminated with malign bacteria. There have been enough instances discovered where a troublesome " fault " in the cheese has been traced to the milk from a single dairy to indicate that in the successful method of cheese-making of the future it will be necessary to have a more careful control over the kinds of milk used in the manufacture of cheese.

It has been suggested that perhaps it may be necessary to use the same process of pasteurization for the purpose of getting rid of such possible errors as is used in the butter manufactories. The pasteurization of the milk for cheese-making has as yet, however, not been applied in any cheese factory. A few experiments have been made by bacteriologists to determine whether it is possible to pasteurize the milk without injury to its curdling powers under the influence of rennet. Of course, if such were not the fact, it would follow that pasteurization could never be used with success in cheese-making. These tentative experiments have indicated that when the time comes that bacteriologists can offer promise of a great surety in the results, pasteurization of the milk for cheese-making is perfectly feasible, for when it is properly conducted the milk will be curdled by the rennet in a perfectly normal fashion.

Almost the only practical application of bacteriology in general cheese-making which has been introduced as yet has been in the development and the application of a so-called

"fermentation test" designed for the purpose of enabling the cheese-maker to exclude from his cheeses any milk which is likely to produce trouble. Its application is extremely simple, and there have already been devised and put upon the market forms of apparatus which make it convenient to use in ordinary cheese factories. It consists simply in testing separately samples of milk from each patron. The essence of the process is merely this: A small sample of the ordinary milk is put in a special vessel by itself, and is then subjected to a moderately warm temperature and carefully watched. If the milk is found to curdle in a proper time in a normal fashion it is regarded as perfectly safe to use; but if the milk becomes full of gas bubbles in the curdling, if the nose or the tongue detects any specially unpleasant or unusual qualities, it is inferred that the milk is filled with bacteria that will be deleterious to the process of cheese-making. When this occurs the milk from the sources from which the sample is taken is not allowed to be mixed with the ordinary milk for the purpose of making the cheese. This fermentation test is not used very widely. As a rule cheese is made to-day practically as it was fifteen years ago, before any knowledge of bacteriology was obtained. But cheese-makers have learned that this fermentation test may be used at time of trouble and may be used as a means of discriminating milk that can be safely put into cheeses from that which it is not safe to use in this way. The practical difficulty in the way of the test is, of course, that the cheese-maker may not discover until weeks after the cheeses are made that they are likely to develop certain undesirable faults, and by this time the fermentation test is of comparatively little use. The original source of error has very likely disappeared, and the application of the fermentation test after the discovery that the cheeses are liable to "faults" is too late to be of much use. Nevertheless the fermentation test has been in some cases found to be of practical value.

The success of the use of pure cultures in improving the quality of butter, and the manifestly close relation between the form of fermentation in ripening cheese, and the character of the cheese, suggests, of course, a very great possibility of the application of pure cultures to the process of cheese-making. If it is true that the flavors of different kinds of cheeses are due to different species of bacteria or moulds, it ought to be possible to use pure cultures of the proper species in such a way as to give rise to perfect uniformity in the results, and to make it

possible to produce in any part of the globe any particular kind of cheese. It is along this line that bacteriologists are working to-day, hoping that by an extension of their experiments they will learn what kind of pure cultures can be used in cheese-making to give the most desirable results. Up to the present time, however, no practical results in this line of work have been reached. There is, it is true, one European bacteriologist who has put upon the market a pure culture of bacteria for cheese-making, making great claims for it, as giving rise to a very high grade of cheese with uniform results. It has not been as yet used to any very great extent, and, certainly, has as yet no very great reputation. There is another who has succeeded in making fine cheeses by the use of certain species of moulds. Beyond this, while other bacteriologists have species of bacteria which in their laboratory experiments have produced very desirable results, and have given rise to cheese with flavors that appear to be normal and uniform, the application of the method of the artificial use of bacteria in cheese-making has scarcely extended beyond laboratory experiments, and in practical cheese-making is as yet almost unknown.

SLIMY WHEY CHEESE OF HOLLAND.

There is, however, in Holland a practical application of bacteriology to cheese-making which has been derived not from laboratory experimentation, but rather from dairy practice. In the manufacture of the common Holland cheeses, of which the Edam cheese is best known to us, the ordinary method is to make the milk from a single day's milking into one or more small cheeses and to allow these cheeses to ripen under perfectly natural processes. It takes, however, a number of weeks to produce the ripening of such cheeses, and they are not ready for market for about six weeks. Moreover, there is no absolute uniformity of results.

There has been introduced into Holland a method of hastening this ripening process and producing a greater uniformity of result by the use of what is known as "slimy whey." This slimy whey is nothing more than a milk culture of bacteria, and it is carried by the cheese-maker from day to day as a butter-maker keeps his starter. A certain quantity of the material is added to the milk which is to be made into the cheese.

A study of this slimy whey shows that it is a culture of a number of varieties of bacteria and yeasts, and that prominent among them is a certain micrococcus which has the power of rendering the milk very slimy. When this organism grows in milk alone its effect is not very great, and it produces no slime. When, however, it grows in company with yeasts which consume the dissolved oxygen the milk becomes slimy. Although there may be several organisms together in this starter the slimy micrococcus appears to the primary one, for all instances of good slimy whey which are used in cheese-making contain this organism. In the last few years the use of this slimy whey in Holland cheese-making has increased until at the present time something like one-third of the cheese which is made in Holland is made by means of this artificial starter.

The results of its use are both favorable and unfavorable. In the first place, the ripening is hastened and the cheese is ripened considerably sooner than is cheese which is ripened without such a starter. It is ready for market in four weeks instead of six. In the second place, the ripening is more uniform, and the farmer that uses the starter is more sure of getting desirable results than the farmer who makes his cheese without it. These two factors, of course, are very desirable ones. But, on the other hand, the character of the cheese is somewhat different from that of the natural cheese, its consistency varies slightly so that the expert can determine at a glance whether the cheese has been ripened with the slimy whey or not. Again, the character of the ripening is thought to be slightly inferior, the flavor obtained not being equal to that of the best cheeses obtained by a natural method; and, lastly, the keeping quality of the cheese flavor appears to be somewhat less than that of natural cheese. The buyers who wish cheese for exportation buy almost wholly the cheese made by natural processes, while cheeses that are bought for immediate sale and immediate use are more likely to be those made by the artificial starter. The Edam cheeses that we obtain in this country are, therefore, nearly all of them made by the natural process. In the use of this slimy whey the farmer is obliged to renew his stock culture frequently, for his starter runs out in the course of time. On some farms, indeed, it is found impossible to keep these starters pure for more than a short time, and they must be constantly renewed, while on others, for

reasons yet unknown, they can be kept for week after week without difficulty.

There is little question that if the cheese manufacturing in Holland was carried on in larger factories this process of the use of artificial starters would be developed much more rapidly and more successfully than it has been. The majority of Holland cheeses are made in individual farms, and a farm in Holland is a very small tract of land. Such a farm will frequently make only one of these small cheeses a day; if they make three it is exceptional. Of course, some larger farms will make more. But where the cheese is made in such small quantities there is no special incentive and no opportunity for the development and application of new methods by experiment. There have in the last few years been started some cheese factories where a larger amount of milk is received daily from many farms and where these Holland cheeses are made in large quantities. Up to the present time, however, the cheeses thus made are decidedly inferior to those made on the farm, a fact that is in considerable measure due to the use of the same methods that have given a bad reputation to American cheese. Instead of using whole milk, skim milk or half skim milk is used, and the quality of the cheese is in consequence deteriorated. It is certainly within the region of probability that these larger factories in the future, through the assistance of the experiment stations that are working upon the subject of slimy whey, will develop this method and obtain more valuable applications. But even at present the use of slimy whey is adopted on one-third of the cheese-making farms, and its use is apparently extending because of the greater rapidity of ripening, and the greater uniformity which it brings.

Except in these few directions bacteriology has as yet played no part in practical cheese-making. It is the confident belief of bacteriologists that there is a greater future for the application of their results in this direction than in any other, and they are convinced that a few years will see the use of pure cultures in cheese-making developed to an extent much greater than it has been yet developed in butter-making. Up to the present time, however, the cheese-makers say that bacteriology is very interesting, but it has given them almost nothing that is practical for their use.

IV. SUMMARY OF MORE IMPORTANT APPLICATION OF DAIRY BACTERIOLOGY IN EUROPE.

The following is a summary of the statements above regarding the more important practical applications of bacteriology to dairying in Europe:

1. A knowledge of the action of bacteria upon milk has led to a very careful guarding of milk from contamination. This has been directed first to the cow, second to the conditions in the cow stall, third to the cleaning of the milk vessels, and fourth to the methods of handling the milk.

2. The demonstration of the agency of milk in distributing disease has led to the taking of great pains to prevent the milk from coming in the vicinity of disease germs. This has resulted in (1) the attempt to exclude all persons, who have contact with contagious diseases, from any participation in handling the milk; (2) greater care in regard to the water used in the dairy; and (3) the attempt to exclude from the dairy herd all animals suffering from any sort of udder disease.

3. Proper regulations can be better enforced by large business firms than by public statute, and partly as a result of this, the milk supply of the large cities is passing into the hands of a few large firms.

4. As the public has learned how disease is distributed by milk the demand for sterilized milk has grown until it can be purchased in most cities from the ordinary milk men. The dislike of the taste of sterilized milk and the belief that sterilizing makes it somewhat less easily digested have led to the adoption of the process of pasteurizing, though it is rather slow in coming into use.

5. The use of bacteria cultures for cream ripening in the process of butter-making is confined chiefly to Denmark and North Germany. In Denmark over ninety-five per cent. of the butter is made by the use of artificial pure cultures of bacteria inoculated into pasteurized cream. The results have been highly satisfactory to the Danish butter-makers. Oleomargarine is largely made by the use of pure cultures.

6. Up to the present no important practical applications of bacteriological knowledge have been made in the process of cheese-making. The only instance in practice where bacteria are artificially inoculated into milk to produce cheese ripening is in the use of "slimy whey" in the making of Holland cheeses.

TUBERCULOUS COWS, AND THE USE OF THEIR MILK IN FEEDING CALVES.

By C. S. Phelps.

In October, 1896, arrangements were made with the Connecticut State Cattle Commission by which four condemned Devon cows were placed at the disposal of the Station for the purpose of making some observations and experiments on tuberculosis. The herd from which the animals came was officially tested with tuberculin by the Cattle Commissioners in March, 1896, and several of the animals in the herd were condemned and slaughtered. At that time the four animals, which were later taken for experiment, failed to respond (see page 101.) These were officially tagged as free from the disease, and were numbered 1337, 1341, 1343, and 1344.

In October, 1896, the herd was again tested with tuberculin by the same commissioners, and the four cows just referred to responded to the test (see page 101), and were shortly afterward placed at the disposal of the Station, and have been kept in quarantine since that time.

The appearance of the disease in animals which seven months before were pronounced sound may, perhaps, be accounted for in one of three ways. First: The disease may have been present at the time of the first test, and, through failure on the part of the tuberculin to react, its presence was not revealed. Second: At the time of the first test the germs may have but recently found lodgment in the animals. In this case the disease might have been so little developed as not to cause a response to the test. Third: The disease germs may have been acquired by these cows after the first test was made, owing to insufficient care having been used in disinfecting the stables.

These particular animals were chosen for experiment, because there was good reason to believe that the disease was present in its earlier stages. One object in view was to study the effect of the milk of slightly diseased cows when fed to healthy calves, and also the relative danger from the spread of the disease by association with diseased animals.

The following table gives the temperatures in the two tests made before the cows came to the Station. The numbers for the cows which were used in these earlier tests have been retained by the Station:

TABLE I.

*Tuberculin tests made with cows prior to their arrival at the Station.**

NUMBER OF COW.	BEFORE INJECTION.		AFTER INJECTION.				
	8 P. M.	10 P. M.	6 A. M.	8 A. M.	10 A. M.	12.M.	2 P. M
Test made March 14–15, 1896.							
1337, ...	102.2	102.8	102.3	102.6	103.0	102.4	102.4
1341, ...	101.1	101.3	101.6	102.2	102.2	102.4	102.0
1343, ...	101.0	101.6	101.8	101.8	102.1	102.1	102.2
1344, ...	101.0	101.5	100.7	101.6	101.4	102.0	101.4
Test made October 26–27. 1896.							
1337, ...	101.3	101.4	100.6	101.6	103.0	**104.4**	**104.8**
1341, ...	101.6	101.4	100.8	101.7	102.4	**104.4**	**105.6**
1343, ...	102.0	101.7	99.6	101.6	102.8	**104.4**	**105.0**
1344, ...	101.8	101.1	102.0	102.0	**105.0**	**105.8**	**105.6**

Care of the cows, and tuberculin tests after they were taken in charge by the Station. — When the cows were brought to the Station they were placed in a high, light, and airy stable, affording about 1,500 cubic feet of air space per cow, although later several calves occupied the same stables with the cows. The Station barn is located about eighty rods from the College barn, and the tuberculous animals have been kept separate from any other cattle. Adjoining the stables is a yard about one-half acre in area, where the animals can exercise. In mild weather they have occupied the yard most of the day. No special treatment for the disease has been attempted, but good care and feed have been afforded at all times. Plans were made whereby the animals could be subjected to the tuberculin test from time to time. These tests were, in most cases, made by the College veterinarian.

* Through the courtesy of the former Secretary of the State Cattle Commission we are able to publish the temperatures obtained in the tuberculin tests made prior to the arrival of the cows at the Station. These tests were made by Dr. L. J. Storrs.

The first test after the cows reached the Station was made by the College veterinarian, Dr. George A. Waterman, January 26-27, 1897. This was three months after the animals were condemned by the Cattle Commissioners. All four of the cows responded clearly to the test. In addition to the necessary rise of temperature (two degrees above the maximum before injection), to indicate the presence of the disease, cow No. 1337 showed a roughness of the hair at 9.30 A. M., the 27th, and Nos. 1341, 1343, and 1344 each showed a decided chill between 9.30 A. M. and 3 P. M. The next two tuberculin tests were made by the same veterinarian. Three months later, April 26th-27th, all four of the cows were injected. At that time cows Nos. 1341 and 1344 responded to the test, while the other two cows showed no apparent results. None of the cows manifested any signs of chill. The next test was made about four months later, July 30th-31st. At that time none of the cows gave an appreciable rise of temperature, nor did they manifest any physical symptoms, such as chilling or roughness of the hair. Late in September it was thought desirable to repeat the test, and as the College was temporarily without a veterinarian, the services of Dr. L. J. Storrs were engaged. No response either in rise of temperature or physical symptoms was observed.

The tuberculin tests which were made in December, 1897, April, 1898, and December, 1898, were conducted by Dr. N. S. Mayo, the present College veterinarian. In these tests the temperatures before injection were taken every three hours throughout the day, but only the maxima and averages for the day are given in the table. In the test made December 17-18, 1897, cow No. 1344 showed a marked rise of temperature, while the other three showed no response. In the test made April 11-12, 1898, cow No. 1343 responded, while the other three cows did not. Cow No. 1344 showed a slight rise of temperature at 4, 6, and 8 P. M., the day after injection, but she was observed to be in heat at this time, a condition which would doubtless account for slight abnormal temperatures.

TABLE 2.

Tuberculin tests of tuberculous cows, and of calves which were fed their milk.

DATE OF TEST AND NUMBER OF ANIMAL.	BEFORE INJECTION.		AFTER INJECTION.							
			6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.	4 P. M.	6 P. M.	8 P. M.
Jan. 26–27, 1897.	5 P.M.	9 P.M.								
1337, -	101.0	101.2	101.5	102.1	**104.0**	**105.2**	**106.1**	—	**104.8**	—
1341, -	102.2	101.5	102.1	102.5	103.6	102.6	103.2	**104.9**	**106.1**	—
1343, -	100.9	100.3	101.4	102.0	102.9	**105.1**	**106.2**	—	**105.0**	—
1344, -	100.6	100.1	101.2	101.6	103.0	**105.0**	**105.9**	—	**105.6**	—
A (calf), -	102.0	102.0	101.5	101.1	101.4	101.6	101.6	—	102.2	—
March 3–4.	4 P.M.	9 P.M.								
B (calf), -	102.7	103.4	102.1	102.6	102.2	101.5	101.7	—	—	—
Mar. 29–30	5 P.M.	9 P.M.								
A (calf), -	102.4	102.6	102.4	102.0	101.7	101.9	102.4	—	—	—
Apr. 26–27.	5 P.M.	9 P.M.								
1337, -	103.7	102.0	102.4	102.2	102.0	102.2	102.0	—	—	—
1341, -	102.8	101.5	102.6	103.7	**105.2**	**106.0**	**105.8**	—	—	—
1343, -	102.0	101.6	102.0	102.0	102.2	102.0	101.8	—	—	—
1344, -	101.6	101.0	102.5	103.4	**103.8**	**103.8**	102.8	—	—	—
July 30–31.	5 P.M.	11 P.M.								
1337, -	101.8	101.3	102.2	102.0	102.2	102.1	102.2	101.3	102.4	102.1
1341, -	101.6	101.0	102.5	102.8	101.9	101.8	101.5	101.2	101.3	101.0
1343, -	101.8	101.0	102.8	102.7	102.1	102.2	102.0	101.8	101.4	101.4
1344, -	101.1	100.6	102.1	102.4	101.7	102.0	102.0	102.0	102.0	101.0
A (calf), -	102.5	101.8	101.8	101.8	101.4	102.0	101.8	—	—	—
B (calf), -	101.8	101.9	101.2	101.4	101.6	101.6	101.9	—	—	—
C (calf), -	103.0	102.0	101.8	101.5	101.7	101.8	102.4	—	—	—
Sept. 27–28.	8 P.M.	10 P.M.								
1337, -	—	101.8	102.0	102.1	101.9	101.6	101.6	—	—	—
1341, -	—	101.5	101.3	101.2	101.5	102.0	101.8	—	—	—
1343, -	—	101.7	101.5	101.6	101.5	101.3	101.5	—	—	—
1344, -	—	101.0	101.1	101.4	101.2	101.2	101.1	—	—	—
A (calf), -	102.6	101.6	101.6	101.4	101.7	101.8	102.0	—	—	—
B (calf), -	102.3	101.7	101.7	101.3	101.0	101.2	101.5	—	—	—
C (calf), -	102.4	101.6	101.8	101.4	101.7	101.8	101.8	—	—	—
Dec. 17–18.	Maximum	*Average.								
1337, -	102.8	101.6	101.3	101.7	102.9	102.9	102.6	102.5	103.0	103.5
1341, -	102.2	101.3	101.2	102.0	102.3	103.0	102.2	102.6	102.1	101.5
1343, -	102.2	101.5	101.1	102.0	101.9	102.4	102.0	101.8	101.0	101.8
1344, -	102.3	101.0	101.5	102.2	**104.4**	**106 4**	**107.0**	**105.7**	**104.4**	102.8
A (calf), -	101.8	101.1	100.8	101.8	101.6	101.6	100.9	102.2	101.8	101.0
B (calf), -	101.8	101.3	101.0	101.2	101.0	101.2	101.9	101.7	102.2	100.8
C (calf), -	102.2	101.4	101.0	101.5	101.2	101.4	101.7	101.7	102.2	101.4
D (calf), -	102.6	102.1	102.0	101.7	101.2	102.0	101.8	102.0	102.0	102.0

TABLE 2.—(*Continued.*)

Date of test and number of animal.	Before injection.		After injection.							
			6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.	4 P. M.	6 P. M.	8 P. M.
Apr. 11–12, 1898.	Maximum	*Average.								
1337, -	101.8	101.3	101.8	102.6	102.3	102.2	101.8	101.8	101.9	102.0
1341, -	101.8	101.3	102.0	102.6	102.4	102.6	101.9	102.0	101.8	101.6
1343, -	102.1	101.5	102.3	**104.0**	**104.2**	**104.5**	**104.0**	102.5	101.9	102.0
1344, -	101.2	100.8	101.7	102.5	102.7	102.8	102.7	103.0†	103.2†	103.0†
A (calf), -	102.2	101.4	101.6	101.8	101.6	102.0	101.8	101.3	102.0	102.0
B (calf), -	101.9	100.9	100.5	101.0	100.6	100.6	100.8	100.5	101.4	101.4
D (calf), -	102.3	101.8	102.3	101.8	101.7	101.7	102.0	102.7	102.6	102.6
Dec. 22–23, 1898.										
1337, -	103.0	101.9	101.2	102.2	102.9	102.0	101.9	101.3	101.3	—
1341, -	103.0	101.7	102.6	103.8	103.9	100.0	100.8	102.1	101.9	—
1343, -	103.0	102.1	104.2	103.8	103.8	101.5	102.1	102.3	101.7	—
1344, -	102.4	101.4	101.6	102.0	102.4	101.4	100.8	101.1	101.3	—
A (calf), -	102.5	101.5	101.4	101.7	102.2	102.6	103.1	102.5	102.5	—
B (calf), -	102.2	101.7	**104.4**	**106.2**	**106.3**	**104.9**	**106.0**	**105.3**	**105.0**	—
C (calf), -	102.2	100.6	102.1	102.3	101.4	101.6	102.9	101.6	—	—
D (calf), -	102.2	101.9	101.6	102.2	101.8	102.0	101.7	101.9	101.9	—
E (calf), -	102.8	102.0	101.5	101.7	101.4	102.1	101.7	101.8	101.6	—
F (calf), -	103.3	102.1	102.0	102.0	101.6	102.5	101.6	101.6	102.7	—
G (calf), -	103.0	102.6	101.4	101.8	100.8	102.2	103.1	102.9	102.2	—
H (calf), -	102.4	102.0	102.6	101.4	101.5	101.2	101.4	101.4	101.8	—

Three of the cows, No. 1337, 1341, and 1343, were due to calve in August or September, 1898, and for this reason it was thought best to discontinue the tuberculin tests for several months. These three cows were dried off during the latter part of June, and were placed in a small pasture separate from all other stock, where they were allowed to remain until they were about ready to calve. The next tuberculin tests of the cows were made December 22 and 23, 1898, and at that time none of the cows gave any response, either in physical symptoms or rise of temperature.

PHYSICAL CONDITION OF THE COWS FROM OCTOBER, 1896, TO FEBRUARY, 1899.

Cow No. 1337. This animal was a heifer which had produced one calf prior to coming to the Station in November, 1896. She was due to calve in April, 1897. She remained in

* Average of temperatures taken every three hoursM.-12 P. , 6 A. M.

† Noticed to be in heat at 8 P. M.

fair flesh during the winter of 1896-7, and was dry about three months. She dropped a strong heifer calf on April 5th. From birth till September 20th the calf sucked its dam. During this time the cow seemed a little thin in flesh, although not noticeably so considering her condition of milk. This cow gained in size and flesh during the winter of 1897-8. She was kept at pasture while dry, from the latter part of June until September 15, 1898, at which time she dropped a strong, vigorous heifer calf. The calf has sucked its dam from birth to the present writing (February, 1899). For the first two months after calving the cow seemed a little thin in flesh, but at the present time she is in good order. This cow has had no cough since she was brought to the Station, and has looked strong and vigorous, eating well and appearing in good health at all times.

Cow No. 1341. This cow was pregnant at the time she was brought to the Station in November, 1896. The exact time that she was due to calve could not be ascertained, but it was supposed that she would calve in March or April, 1897. She was dry for about two months, and dropped a dead calf March 2, 1897. The foetus was well covered with hair, and appeared to be premature by about one month. A careful physical examination of the calf, made by the College veterinarian, failed to show the presence of tuberculosis, and cultures made from several sections of the body failed to reveal the germs of tuberculosis. The cow was quite thin in flesh for about three months after calving, but gained slightly during the following summer. She was quite a heavy milker, and this fact may account in part for her thinness in flesh. During the winter of 1897-8 she gained in flesh, and in April, 1898, appeared in fair physical condition. At times during the winter she had a chronic looseness of the bowels, but no cough was observed. This cow was dry from about the middle of June until the time of calving, August 11, 1898, and during this period she was kept at pasture. For about a month after calving she seemed to be running down in flesh, but soon began to gain, and by the time the cows were placed in their winter quarters she was in fair flesh. She has produced quite a heavy flow of milk ever since dropping her last calf. At the present time (February, 1899) she seems to be a little thin in flesh, although no cough has been noticed. She continues to eat well, and appears in a fair state of health.

Cow No. 1343. This cow produced a calf in September or October, 1898. She is a lighter milker than the other cows, has a somewhat beefy form, and shows a tendency to lay on fat. During the winter of 1897-8 she became quite fat and sleek. In March, 1898, she was noticed to have a slight cough, but otherwise appeared in good physical condition. She was dried off about the middle of June, and was placed at pasture. August 28, 1898, she dropped a small heifer calf. For two or three months after calving she became somewhat thinner in flesh than usual, but soon after being placed in winter quarters she began to gain. From November, 1898, to the present time (February, 1899), she has had quite a persistent cough. Otherwise she appears in a fair state of health, although not quite as fat as during the winter of 1897-8.

Cow No. 1344. This cow calved in September or October, 1896. She gave a fair flow of milk during the winter of 1896-7, and became quite fat and beefy. During the summer of 1897 this cow became rather thin in flesh, although she had no cough, and appeared in good physical condition. Although several attempts were made to have this cow become pregnant, she remained "farrow" throughout the winter of 1897-8, and since that time. At the present writing (February, 1899) she has continued to produce milk without interruption for nearly two years and a half. During the present winter she has become fatter than usual, and from general appearances seems to be in a good state of health.

On May 8, 1898, and again February 7, 1899, the College veterinarian made careful physical examinations of the animals. The reports which he has made as to the physical condition of the cows is appended to this article.

Physical Examinations.

On May 8, 1898, Prof. N. S. Mayo, the College veterinarian, made a physical examination of the animals. The report of this examination was given in the article on the subject in the last report of the Station for 1898. It is reproduced here for comparison with the report of the examination made by the same veterinarian on February 7, 1899. These reports are as follows:

Report of Veterinarian, May 8, 1898. — It is a fact well recognized that bovine tuberculosis, unless well advanced, is one of the most difficult diseases to diagnose upon a physical examination.

Of the seven animals examined four are the Devon cows that have been tested and found to respond at one time or another, three (A, B, and D) are young bulls that have been fed with the milk of the cows. The calves have not reacted to the tuberculin test, and a careful physical examination fails to reveal any indications that they have tuberculosis.

Of the four cows that have responded to the test, No. 1337 presents no symptoms of tuberculosis. She is in good flesh and looks well. Her temperature was 102.2° F., respiration full and at the rate of twelve per minute.

Cow No. 1341 is thinner in flesh than any of the others, and seems to be affected with a slight but chronic looseness of the bowels. Her temperature was 102° F., and respirations twelve per minute.

Cow No. 1343 is rather fat. She is troubled with a chronic cough, and auscultation indicates that the anterior (cephalic) lobes of the lungs, especially the right, are tuberculous. Her temperature was 102.6 F., and respirations are twenty-two per minute. Cows Nos. 1337, 1341, and 1343 are pregnant.

Cow No. 1344 is in good flesh. Temperature 101.8° F., and respirations fifteen per minute. Nothing abnormal could be detected upon a physical examination. No enlarged glands could be detected in any of the animals examined. Of the four cows that have at some time responded to the test, Nos. 1337 and 1344 show no symptoms of the disease having developed. In No. 1341 the chronic looseness of the bowels may be considered as a suspicious symptom of a tubercular affection of the digestive tract. In No. 1343 the physical symptoms indicate tuberculosis of the lungs.

It must be remembered that all of these animals have had good care and attention, and have not been exposed to conditions or circumstances that would cause the disease to develop.

Report of the Veterinarian, Feb. 7, 1899. — Of the four Devon cows examined, No. 1337 does not seem to be in as thrifty condition as she ought to be, considering her care and feed. No. 1341 is not in as thrifty condition as No. 1337, and would probably be condemned as tuberculous on a physical examination. Nos. 1343 and 1344 are in excellent condition, physically, both being rather fat, and are looking well. The only evidence of disease is found in No. 1343, her respirations not being as full and deep as they should be normally. No cough was noted in any of the animals.

N. S. Mayo, D.V.S.,
College Veterinarian.

FEEDING CALVES WITH THE MILK OF TUBERCULOUS COWS.

Soon after the cows were brought to the Station, plans were made for feeding their milk to calves from healthy cows, and in some cases to their own offspring. These experiments have been continued for a little over two years. In some cases the calves have been allowed to suck their dams, while in others

they have been fed the milk from a pail. In the experiments for the first year and a half the calves were kept in the same stable with the cows, and, of course, there was some liability that the animals might contract the disease through the breath, or food other than the milk. During this period, however, no sign of the disease was developed in any of the calves. In some later experiments, two of the calves are being kept in a room entirely separate from the cows.

Feeding calf A with the milk of cows 1344 and 1341.— This calf was dropped December 25, 1896, by a vigorous grade cow. The dam of the calf was tested with tuberculin on March 3-4, 1897, but gave no response. This calf was fed the milk of cow No. 1344 from January 7 to March 28, 1897. The calf was tested with tuberculin January 26-27, and again March 29-30, 1897, but gave no response to either of the tests. At that time, the supply of milk from cow No. 1344 being less than the calf seemed to need, it was fed the milk of cow No. 1341. This cow being quite a heavy milker, the calf was limited to about 15 or 16 pounds of milk per day for the first month. After this, calf A was given all the milk produced by cow No. 1341, which amounted to 20-24 pounds daily, for the next two months. Calf A was fed the milk of this cow from about April 1, 1897, to July 9, 1898. The calf was castrated in May, when about a year and a half old, and was sent to pasture July 9, where it remained until about the 1st of November, 1898. Beside the two tuberculin tests made while calf A was being fed the milk of cow No. 1344, several tests were made during the year and three months that it was fed the milk supply of cow 1341. The first of these tests was made July 30-31, the second September 27-28, the third December 17-18, 1897, and the last before the animal went to pasture was made on April 11-12, 1898. At no time since we began feeding this calf early in January, 1897, has it shown any effects from the tuberculin tests, or any physical symptoms that would indicate the presence of the disease. When sent to pasture in July it was a large, vigorous animal, weighing about 500 pounds. Early in November this steer was returned to the same stable with the tuberculous cows. It was again tested with tuberculin December 22-23, 1898, but gave no response. During the present winter it is being fattened for beef, and at the present time (February, 1899) the steer is in vigorous condition, and is laying on flesh quite rapidly.

Feeding calf B with milk of cow No. 1343. — This calf was dropped by a vigorous Jersey cow on February 20, 1897, and was ten days old when the feeding period began. The dam of the calf was tested with tuberculin about a year previous to the birth of this calf, and was pronounced healthy. Calf B, when about two weeks old (March 3-4) was tested with tuberculin and gave no response. From March 1, 1897, to early in July, 1898, calf B was fed the entire milk supply of cow No. 1343. This calf has not been a vigorous eater, and at times has refused single feeds of milk. The calf has seemed healthy and has eaten hay readily. When a year old, the animal was thought to be rather small for its age, but this may have been due to the fact that he had always refused grain feeds. Besides the test with tuberculin at the beginning of the feeding period, calf B was also tested July 30-31, September 27-28, and December 17-18, 1897, and April 11-12, 1898. This animal was also castrated in May, 1898, and was sent to pasture with calf A July 9, where it remained until November, 1898. It was returned to the same stable with the cows early in November, and was started upon a heavy grain ration, with a view to fattening for beef. When tested December 22-23, this steer gave a marked response to the tuberculin test. (See temperatures, Table 2, page 104.) In addition to a marked rise of temperature, the steer showed physical symptoms of roughness of the coat, shivering, and twitching of the muscles. Steer B was killed and carefully examined by the College veterinarian December 30, 1898. The only trace of the disease found was a few tubercles in one of the pharyngeal glands of the throat. The disease was without doubt of recent origin. Had the disease been produced by the milk upon which the animal was fed for sixteen months before going to pasture, the disease would, doubtless, have appeared first in the digestive tract. While, of course, there is no positive proof as to how this animal contracted the disease, it seems most probable that the germs entered the system in the breath after the animal was returned to the stable early in November, 1898.

Feeding calf C with milk of cow No. 1337. — This was a heifer calf dropped by cow No. 1337 April 5, 1897. The calf was allowed to suck its dam until about six months old. About October 1st the calf was weaned, but was fed the milk of the dam till January, 1898. It was then gradually changed

on to a skim-milk diet, and was placed in the College herd, with the intention of raising the calf for dairy purposes. Calf C was tested with tuberculin July 30-31, September 27-28, and December 17-18, 1897. During the summer of 1898 the calf was kept at pasture with other young stock, and made a vigorous growth. It was tested with tuberculin December 22-23, 1898, but gave no response. It is now nearly two years old, and is a large, vigorous animal.

Feeding calf D with milk of cow No. 1344. — This calf was dropped by a vigorous grade cow November 29, 1897. The dam was tested with tuberculin March 3-4, 1897, but gave no response to the test. The calf was first subjected to the tuberculin test December 17-18, but gave no response. Calf D was again tested April 11-12, 1898, but did not respond. This calf had all the milk produced by cow No. 1344 (about 10-12 pounds daily) from early in December, 1897, up to the present time (February, 1899). The last tuberculin test was made December 22-23, 1898, with no response. The animal has made a rapid growth and is a large, vigorous yearling at the present time.

From the records just given of the feeding of these four animals, it will be seen that each consumed the milk of a separate cow for periods varying from three months to a year and four months, and that in no case was there any sign of the disease having been contracted during these feeding periods. One animal (B) did respond to the tuberculin test nearly six months after the feeding period with milk was ended, but from the mild form in which the disease existed, and its location, it seems very doubtful if the disease was contracted through the milk. These tests point to the conclusion that the milk is not as dangerous a source of infection as has been commonly supposed.

As has already been stated, three of the cows, Nos. 1337, 1341, and 1343, produced calves in August and September, 1898. All of the calves have been fed the milk of their dams since being dropped, down to the present time (February, 1899).

Feeding calves E and F. — Calf E was a large heifer calf, dropped by cow No. 1341, August 11, 1898, and calf F was a bull calf, dropped by a grade cow in the College herd. This cow was supposed to be healthy, but within three months after

the birth of the calf developed a severe case of tuberculosis.* The calf dropped by this cow has appeared healthy and vigorous from the first. The plan of the test with these two calves was to pasteurize one-half the milk of cow No. 1341 and feed it to its own offspring, calf E, and to feed the balance of the milk, in its normal condition, to a calf from a healthy cow. Calf F was chosen for this purpose, because it was supposed that its dam was free from tuberculosis, not having responded to the test made December 30-31, 1897.

The feeding test has been continued the same as though this calf was from a perfectly healthy cow. Both of these calves have been kept in a room entirely separate from the tuberculous cows, and the two calves have been separated from each other by a double slat partition in such a way as to prevent their licking one another. The portion of the milk of cow No. 1341 which was fed to calf E has been heated to a temperature of from 170-175° F., and diluted with cold water before feeding. The balance of the milk of the same cow, in its normal condition, has been fed to calf F as soon as possible after milking. Both calves have had a small quantity of bran added to the milk since they were about two months old. These calves were tested with tuberculin December 22-23, 1898, after having been fed the milk of cow No. 1341 for about four months, but gave no response to the test. Both have grown rapidly, and are in a strong, vigorous condition at the present writing (February, 1899).

Feeding calf G. — This was a small heifer calf dropped by cow No. 1343, August 28, 1898. The calf was small at birth, and has appeared rather puny ever since. It has been fed the milk of its dam since birth, although it has not eaten well, and has only consumed small quantities of milk. The calf has seemed to lack vigor, and has remained thin in flesh and has grown slowly. It did not respond to the tuberculin

*This cow was tested with tuberculin December 30-31, 1897, but gave no response to the test. She calved August 27, 1898, and appeared in a healthy, vigorous condition until the herd was placed in winter quarters early in November. Soon after, she began to refuse silage, and dropped off rapidly in milk flow, but manifested no serious symptoms until about ten days after she began to refuse silage. At that time the cow began to scour badly, and was placed in a box stall away from the rest of the herd For the next ten days she ran down in flesh rapidly so that it was thought wise to destroy her. A *post mortem* examination showed a severe case of tuberculosis, the tubercles being present in the liver, the spleen, and the lungs. Some of the lesions were encysted in such a way as to indicate that the disease was one of long standing, and it is probable that the tuberclin test which was made eleven months previous to the time of killing the cow failed to cause a response, owing to the advanced condition of the disease, or the failure may have been due to a poor lot of tuberculin. The cow showed no outward appearance of the disease, and remained in good condition of flesh until she began to refuse her feed early in November, 1898.

test which was made December 22-23, after it had been feeding upon the milk of its dam for nearly four months.

Feeding calf H. — This was a strong, vigorous heifer calf, dropped by cow No. 1337, September 14, 1898. The calf has suckled its dam for the past four months, and has grown rapidly. It was tested with tuberculin December 22-23, 1898, but gave no response. At the present time (February, 1899), this calf is a large, vigorous animal, and is growing rapidly.

DEDUCTIONS.

We know comparatively little regarding the conditions which favor the spread and development of tuberculosis among animals or man. Most of all are we lacking in a definite knowledge of the dangers of this disease to mankind from the bovine race. Many have claimed that the danger to mankind from the spread of the disease through the milk supply is very great. It has generally been thought that one great cause for the spread of the disease among our herds is the feeding of the milk of tuberculous cows to calves. The experiments made during the past two years at this Station do not substantiate this view. It must be borne in mind, however, that the number of experiments is comparatively few, and that the cows whose milk was used were probably in the earlier stages of the disease. These facts have been carefully considered, and it is of course unwise to attempt to draw any definite conclusions from the work, but the following deductions seem warranted:

(*1*) *Bovine tuberculosis is usually a disease of slow development, its progress depending quite largely upon the general vigor of the animal and its power to resist the action of the germs. In nearly two years and a half that the tuberculous cows have been at the Station, only one secondary case has appeared, and this was discovered about six months after the feeding period with milk had ended.*

(2) *In the experiments here reported, eight calves have been fed upon the milk of tuberculous cows for periods varying from three months to sixteen months without developing the disease.*

(*3*) *The results of these experiments coincide with the general results of European observations, and indicate that the danger from the spread of tuberculosis through the milk of cows to man or to other animals is not as great as has generally been supposed. In the earlier stages of the disease and at all times when the udder is not affected, the danger from the use of the milk is quite limited. Great stress, however, should be laid on the danger of using milk from cows which show any symptoms of udder affection.*

EFFECT OF NITROGENOUS FERTILIZERS UPON THE YIELD AND THE COMPOSITION OF CERTAIN GRASSES, GRAINS, AND LEGUMES.

BY W. O. ATWATER AND C. S. PHELPS.

Soon after its organization, in 1888, the Station took up the study of the effects of nitrogenous fertilizers upon the yields and composition of corn, oats, and mixed grasses. Field experiments on the different crops were undertaken, in continuation of a series which, for a number of years previous, had been conducted on farms in different places at the suggestion of one of us (W. O. A.). These experiments were carried on during a considerable period of years for the twofold purpose: first, of studying, by the effect upon the yields of different crops, the relative economy of different kinds and quantities of nitrogenous fertilizers when used with uniform quantities of mineral fertilizers (phosphoric acid and potash); and second, of studying the effect of the nitrogen of the fertilizer upon the percentage of nitrogen compounds (protein) in the plants.

After a few years the Station began a series of experiments with several species of grasses. These were similar to the experiments with corn, oats, and mixed grasses, except that they were conducted upon very small plots. In these experiments, because the plots were so small, no attempt was made to study the effects of the fertilizers upon the yields. The crops were carefully sampled, however, and the effect of the nitrogen in the fertilizers upon the percentages of nitrogen compounds (protein) in the plants was determined. In some cases these experiments have been continued with the same species of grasses and the same fertilizers on the same plots for several years in succession. Within the past few years the Station has undertaken also a series of experiments upon a few of the legumes, for the purpose of comparing the effects of nitrogenous fertilizers upon the plants of this family with the effects of the same kinds and amounts of fertilizers upon plants of the grass family.

Of all the constituents of fertilizers nitrogen is the most costly. In the standard commercial fertilizers at the present time (1899) nitrogen costs from 11 to 15 cents per pound, while

phosphoric acid and potash cost from 3 to 7 cents per pound.* Furthermore, nitrogen is the most unstable of all the fertilizing ingredients; for if it is available in larger quantities than are immediately used by the crop it is readily wasted in various ways. It is very important, therefore, that the farmer should know the kinds of fertilizing materials and the amounts per acre in which he can use nitrogen for the different crops to the best advantage. In the experiments reported herewith, nitrogen has been supplied in nitrate of soda, in sulphate of ammonia, and in dried blood. Of these materials, nitrate of soda is the one in which the nitrogen is considered most available to the plants; sulphate of ammonia yields its nitrogen a little more slowly, while the nitrogen of organic materials, like dried blood, is commonly the least available. The amounts of each of these materials used in the experiments varied according to the amount of nitrogen required by the experiment, as explained later on pages 117 to 119, under the descriptions of "soil test" and "special nitrogen" experiments.

While nitrogen is the most expensive ingredient in fertilizers, it is at the same time the basis of the costly but very valuable and important ingredient of feeding stuffs, protein. Protein compounds generally contain about 16 per cent. of nitrogen. On most farms in New England the amount of protein produced is much less than is needed for feeding purposes. To supply this deficiency the farmer often has to buy large quantities of such feeds as bran, middlings, cotton-seed and gluten meals, etc. The problem for him, therefore, is to find out how he can increase the amount of protein produced on his farm, and do it more cheaply than he can buy it in feeding stuffs.

There are two ways in which the farmer may increase the amount of protein produced upon his farm. One way is to grow more of the leguminous crops, such as clover, soy beans, and the like, which not only contain large proportions of protein, but gather much of their nitrogen from the air and do not require it in fertilizers. The other way is to increase the relative proportions of protein in the grasses and cereals by the proper use of nitrogenous fertilizers. Both methods are practical, as shown by the experiments summarized in this article. The fact that the yield of the common grasses and the cereals is largely increased by the use of nitrogenous fertilizers, while

*See page 121.

the yield of the legumes is but little affected by their use, has long been known. The power of the legumes to utilize the free nitrogen of the air, though a comparatively recent discovery, is already well known by farmers as well as scientific investigators. The increase in the protein content of cereals and grasses generally, caused by nitrogenous fertilizers, is not widely understood. Indeed, we are not familiar with any previous investigations in which it has been shown upon any considerable scale; and certainly it is not current in writings upon the use and effect of nitrogen in fertilizers.

NUMBER, GENERAL PLAN, AND GENERAL CLASSIFICATION OF THE EXPERIMENTS.

The following table gives a general classification of the experiments showing the kinds of crops thus far experimented with by the Station, the kind of experiment, whether "soil test" or "special nitrogen," the years in which the experiments were conducted, the number of experiments made with each crop, the size and the number of the plots, and the number of analyses made of samples of the products. Details of these experiments may be found in the Reports of the Station for either the year in which the experiment was made or the year following.

TABLE 3.— *Classification*

Crops.	Kind of experiment.	Years in which experiments were made.
Grasses.		
Mixed grasses, . . .	Special nitrogen	1890, 91, 92
Timothy, ...	" "	1891, 92, 93, 94, 96, 97, 98
Orchard grass, . . .	" "	1891, 92, 93, 94, 96, 97, 98
Tall meadow fescue, . .	" "	1893, 94, 96, 97, 98
" " . . .	" "	1891
Tall red top, ...	" "	1896, 97
" "	" "	1891, 92
Brome grass, ...	" "	1896, 98
Tall meadow oat grass, . .	" "	1893, 94
" " . .	" "	1892
Fowl meadow grass, . .	" "	1891
Kentucky blue grass, . .	" "	1892
English rye grass, . . .	" "	1891
Cereals.		
Corn (Maize), seed, . .	Soil test	1888, 89, 90
" " stover, . .	"	1888, 89, 90
" " seed, . .	Special nitrogen	1888, 89, 95, 96
" " stover, . .	" "	1888, 89, 95, 96
Oats, seed, ...	Soil test	1892
" straw, ...	....	....
" seed, ...	Special nitrogen	1890, 92
" straw, ...	" "	1890, 92
Legumes.		
Cow pea fodder, . . .	" "	1895, 96, 97, 98
Soy bean seed, . . ,	" "	1895, 96, 97, 98
Total, ...		

The number of experiments in each category in the table represents the number of separate field experiments in which samples were taken for analysis. Each field experiment included several plot experiments. The same experiments were repeated, in several instances, through quite a number of years. It will be noticed that the number of plot tests and the number of analyses do not agree in all cases. This is due to the fact that in some of the experiments duplicate samples were taken and were analyzed separately; while in a few other experiments samples from plots having nitrogen in the same quantities, but in different materials, were combined and analyzed as one sample. In most of the experiments with cereals the seeds and the straw or stover were analyzed separately. In a few of them, however, only the seeds were analyzed. In the experiments with one of the leguminous crops (the soy beans) it was found impracticable to get the samples of the leaves and the

of the experiments.

Size of plots.	No. of experiments.	No. of plots.	No. of analyses.
20 sq. rods	3	25	46
2 sq. rods	7	28	28
2 sq. rods	7	28	28
2 sq. rods	5	20	20
64 sq. feet	1	2	2
2 sq. rods	2	8	8
64 sq. feet	2	4	4
2 sq. rods	2	8	8
2 sq. rods	2	8	8
64 sq. feet	1	2	2
64 sq. feet	1	2	2
64 sq. feet	1	2	2
64 sq. feet	1	2	2
8, 13⅓, 16, or 20 sq. rods	4	39	35
8, 13⅓, 16, or 20 sq. rods	4	39	35
3 2, 8, or 16 sq. rods	8	129	117
3.2, 8, or 16 sq, rods	8	129	117
13⅓ sq. rods	1	12	12
....	....	....	....
8 or 16 sq. rods	2	26	26
8 or 16 sq. rods	2	26	26
6.4 sq. rods	4	40	51
6.4 sq. rods	4	40	33
. . . .	72	619	612

straw, because the plants dropped their leaves to large extent before the seeds were fully matured.

Soil Test Experiments.— The experiments which have been called "soil tests" were undertaken primarily to learn the deficiencies of the soils in regard to the essential ingredients of plant food, especially the phosphoric acid, potash, or nitrogen needed to produce the given crop. The plan of the experiments for soil tests consists in applying, upon parallel plots of land, fertilizers containing nitrogen, phosphoric acid, and potash. The quantities were generally such as to supply about 25 pounds of nitrogen, 53 pounds of phosphoric acid (P_2O_5), and 82 pounds of potash (K_2O) per acre. These ingredients were applied to different plots singly, in all combinations of two, and finally all three together. The arrangement of the

plots of the experiment, the kinds and quantities of the materials used, and of the principle fertilizing ingredients contained in them are shown in the following outline plan.

*Plan of soil test experiment.**

Plot No.	Materials.		Fertilizing ingredients per acre.		
	Kinds.	Amounts per acre.	Phosphoric acid.	Potash.	Nitrogen.
		lbs.	lbs.	lbs.	lbs.
O	Nothing,	....	....	......	....
A	Nitrate of soda,	160	....	......	25
B	Dissolved boneblack,	320	53	......	....
C	Muriate of potash,	160	....	82	....
D	Dissolved boneblack,	320	53	......	....
	Nitrate of soda,	160	....	......	25
E	Muriate of potash,	160	....	82	....
	Nitrate of soda,	160	....	......	25
F	Dissolved boneblack } mixed minerals	320	53	......	....
	Muriate of potash, } mixed minerals	160	....	82	....
G	Dissolved boneblack,	320	53	......	....
	Muriate of potash,	160	....	82	....
	Nitrate of soda,	160	....	......	25

* Unmanured strips separate the plots.

"Special Nitrogen" Experiments.— The object of these experiments, which were made with corn, oats, and mixed grasses, has been to study the effects of nitrogen in different amounts and combinations upon the different crops. The nitrogen was supplied as nitric acid in nitrate of soda, as ammonia in sulphate of ammonia, and as organic nitrogen in dried blood. Phosphoric acid was supplied as superphosphate in dissolved boneblack, and potassium was supplied in muriate of potash.

The amounts of nitrogen used were 25, 50, and 75 pounds per acre. The quantity of phosphoric acid used was 53 pounds, and of potash 82 pounds per acre. These quantities of phosphoric acid and potash are, on the average, such as analyses indicate may be contained in a corn crop of 60 bushels of shelled corn per acre, with the corresponding stover. It is assumed that the same crop would contain 75 pounds of nitrogen, which amount per acre is accordingly designated as a full ration; and 50 pounds is therefore called a two-third, and 25 pounds a one-third ration. The general plan of "Special Nitrogen" experiments is shown in outline as follows:

*Plan of special nitrogen experiments.**

Plot No.	Materials for fertilizers.		Fertilizer ingredients per acre.		
	Kinds.	Amounts per acre	Phosphoric acid.	Potash.	Nitrogen.
	Preliminary group	lbs.	lbs.	lbs.	lbs.
0	Nothing, ...	....	....	....	....
1	Nitrate of soda, . . .	160	....	....	25
2	Dissolved boneblack, . .	320	53	....	....
3	Muriate of potash, . . .	160	....	82	....
4	{ Dissolved boneblack, . .	320	53	....	....
	{ Nitrate of soda, . . .	160	....	....	25
5	{ Muriate of potash, . . .	160	....	82	....
	{ Nitrate of soda, . . .	160	....	....	25
6	{ Dissolved boneblack, { mixed }	320	53	....	....
	{ Muriate of potash, { minerals }	160	....	82	....
00	Nothing, ...	....	....	....	....
	Nitrate of soda group				
6*a*	{ Dissolved boneblack, { mixed }	320	53	....	....
	{ Muriate of potash, { minerals }	160	....	82	....
7	{ Dissolved boneblack, . .	320	53	....	....
	{ Muriate of potash, . . .	160	....	82	....
	{ Nitrate of soda, . . .	160	....	....	25
8	{ Dissolved boneblack, . .	320	53	....	....
	{ Muriate of potash, . . .	160	....	82	....
	{ Nitrate of soda, . . .	320	....	....	50
9	{ Dissolved boneblack, . .	320	53	....	....
	{ Muriate of potash, . . .	160	....	82	....
	{ Nitrate of soda, . . .	480	....	....	75
00	Nothing, ...	....	....	....	....
	Sulphate of ammonia group				
6*b*	{ Dissolved boneblack, { mixed }	320	53	....	....
	{ Muriate of potash, { minerals }	160	....	82	....
10	{ Dissolved boneblack, . .	320	53	....	....
	{ Muriate of potash, . . .	160	....	82	....
	{ Sulphate of ammonia, . .	120	....	....	25
11	{ Dissolved boneblack, . .	320	53	....	....
	{ Muriate of potash, . . .	160	....	82	....
	{ Sulphate of ammonia, . .	240	....	....	50
12	{ Dissolved boneblack, . .	320	53	....	....
	{ Muriate of potash, . . .	160	....	82	....
	{ Sulphate of ammonia, . .	360	....	....	75
00	Nothing, ...	....	....	....	....
	Dried blood group				
6*c*	{ Dissolved boneblack, { mixed }	320	53	....	....
	{ Muriate of potash, { minerals }	160	....	82	....
13	{ Dissolved boneblack, . .	320	53	....	....
	{ Muriate of potash, . . .	160	....	82	....
	{ Dried blood, ...	200	....	....	25
14	{ Dissolved boneblack, . .	320	53	....	....
	{ Muriate of potash, . . .	160	....	82	....
	{ Dried blood, ...	400	....	....	50
15	{ Dissolved boneblack, . .	320	53	....	....
	{ Muriate of potash, . . .	160	....	82	....
	{ Dried blood, ...	600	....	....	75
0	Nothing, ...	....	....	....	....

* Unmanured strips between the plots.

It will be noticed that the plots are arranged in groups. Upon those of the preliminary group the fertilizing ingredients are applied singly in plots 1—3, and two by two in plots 4—6. The combination on plots 6, 6*a*, 6*b*, 6*c*, is designated as "mixed minerals," and is used as a basis to which the nitrogenous materials are added for the mixtures used upon all the plots of the succeeding groups. As the dried blood has but little, and nitrate of soda and sulphate of ammonia have no phosphoric acid or potassium, the quantities of these mineral fertilizers used are kept constant. By comparing the yields from the plots having "mixed minerals" alone, with the yields from the plots having nitrogenous fertilizers in addition to the mixed minerals, the effects of the nitrogen upon the yield may be learned.

It will be observed, furthermore, that the preliminary group Nos. 1 — 5, with "mixed minerals" No. 6, and No. 7 of the nitrate of soda group are practically the same as Nos. A—G of the "soil tests" described above.

In some of the experiments as actually made, the three numbers of the dried blood group (13, 14, 15) were replaced by mixtures in which nitrate of soda, sulphate of ammonia, and dried blood were used instead of dried blood alone. In several instances the preliminary group or one of the nitrogenous groups was omitted. So-called "nothing" plots, *i. e.*, plots without any fertilizer, were provided before, between, and after the several groups.

Special Nitrogen Experiments on Small Plots.— In the regular special nitrogen experiments as in the soil tests, the individual plots were generally one-tenth to one-twentieth of an acre each. A number of special nitrogen experiments with different species of grasses, however, were made in the grass garden of the Station. In most of these experiments the plots were quite small, being two square rods (one-eightieth of an acre) each, while a few were even smaller. The number of groups and of plots in a group was also reduced, so that there were generally only four plots in each group, comprising a nothing plot, a plot with mixed minerals, a plot with minerals and the one-third ration (25 lbs.) of nitrogen, and a plot with minerals and the full ration (75 lbs.) of nitrogen.

COST OF FERTILIZERS.

In the calculations of the financial gains from the use of the fertilizers the present prices of fertilizing materials have

been used. The cost of mixing the materials, of transportation, etc., is left out of account. The 1899 list of commercial valuations adopted by the New England Experiment Stations* in estimating the value of fertilizers is used. This represents the cash cost of the various ingredients of fertilizers, as found in chemicals offered for sale in the larger markets. In many cases, especially where considerable amounts of fertilizers are used, farmers can buy the fertilizing materials at the prices indicated in the list. The prices upon which are based calculations of gains in this discussion are as follows:

Nitrogen in nitrate of soda, ...	12½ cents per pound.
Nitrogen in sulphate of ammonia, . . .	15 cents per pound.
Nitrogen in organic materials (dried blood), .	14 cents per pound.
Potash in muriate, ...	4¼ cents per pound.
Phosphoric acid (soluble)	4½ cents per pound.

All the phosphoric acid used was estimated as soluble, although a small part of it was probably in the form known as reverted phosphoric acid. The proportion in this form could not be estimated; but as the valuation for reverted phosphoric acid is only one-half cent per pound less than that for soluble, the difference in the final results would be small.

EFFECTS OF NITROGENOUS FERTILIZERS UPON THE YIELDS, AND THE ESTIMATED FINANCIAL GAINS.

The detailed accounts of the experiments found in earlier Reports of the Station give results with regard to the yields and the estimated financial gains. It has seemed advisable to summarize briefly these results, indicating the relation between the yields of the crops and the quantity of nitrogen used in the fertilizer, as well as the relative financial gain resulting from the use of different quantities of nitrogen.

In estimating the financial gains the current market prices are taken as bases of valuation of the crops, as these represent what the farmers would receive or pay for them. The feeding value, however, is influenced considerably by the percentage of protein in the crops, which is left entirely out of account in buying or selling. For this reason, the proportion of nitrogen in the fertilizer that would be most advantageous to the producer if he intended to sell his crop might be considerably less

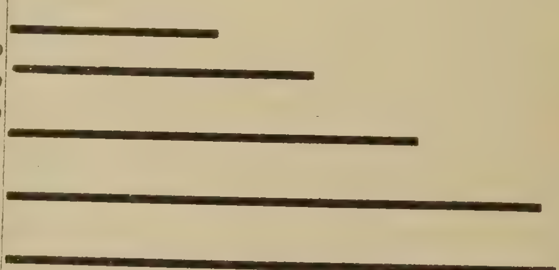
* Not yet published

than he could afford to apply if he intended to feed the crop to his own stock instead of selling it. A discussion of the effects of nitrogenous fertilizers upon the proportion of nitrogen compounds (protein) in the crop will be found in the next division of the subject.

Effects upon Yields of Hay of Mixed Grasses.— During the years 1890, 1891, and 1892, three experiments were carried on with mixed grasses. Ten plots one-eighth of an acre each were used in each of these experiments. Nitrogen was applied upon some of these plots in nitrate of soda and upon others in sulphate of ammonia. Similar effects upon yields of dry matter and protein followed the use of either of these materials in these experiments. The effects of the different quantities of nitrogen when used with uniform quantities of mineral fertilizers are shown in the following table. The weights of the yields per acre represent the averages of the yields from plots upon which the same kinds and amounts of fertilizers were used.

TABLE 4.

Comparison of yields of hay from plots upon which were used fertilizers supplying different quantities of nitrogen.

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.	Yield per acre (11.1 % water).* Comparative scale, 2,600 lbs. to the inch.	lbs.
0, 00	Nothing, . .	....		1881
6a, 6b	Dissolved boneblack, Muriate of potash,	320 160		2664
7, 10	Mixed min. as plot 6a, Nitrogen, . .	480 25		3645
8, 11	Mixed min as plot 6a, Nitrogen, . .	480 50		4727
9, 12	Mixed min. as plot 6a, Nitrogen, . .	480 75		5015

* While the water content of different crops of hay varies with the curing, it has been thought best to calculate the yields upon the basis of 1/9 (11.1 %) water, which appears to be about the average.

From this table it will be observed that the yields increased quite rapidly, in a general way, with the increase in the quantity of nitrogen applied. However, the difference between the yield from the use of 75 pounds of nitrogen per acre, and the yield from the use of 50 pounds per acre, was not so great as the difference between the yield from the use of 50 pounds per acre and that from the use of 25 pounds per acre.

The mineral fertilizers, when used alone on mixed grasses, were applied at a financial loss, as no material increase in the total yield followed their use. They did, however, increase somewhat the yield of clover in the crop, which accords with the results of experiments with legumes discussed on a later page.

From Table 5, which follows, it will be seen that, with the valuation of hay at $12 per ton, in an average of all the similar experiments the profits from the use of 160 pounds of nitrate of soda (25 pounds of nitrogen), was $3.05 per acre; from the use of 320 pounds of nitrate of soda (50 pounds nitrogen), $6.61 per acre; and from the use of 480 pounds of nitrate of soda (75 pounds of nitrogen), $4.47 per acre. The profits from the use of the same amounts of nitrogen in sulphate of ammonia were somewhat less, because the cost of the fertilizer is greater, although the yields of hay were quite similar.

TABLE 5.— *Yields of hay with fertilizers supplying mineral in-*
yields with mineral fertilizers alone,

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.
0	Nothing,	....
7	Mixed minerals, as plot 6*a*,	480
	Nitrate of soda (25 lbs. nitrogen),	160
8	Mixed minerals, as plot 6*a*,	480
	Nitrate of soda (50 lbs. nitrogen),	320
9	Mixed minerals, as plot 6*a*,	480
	Nitrate of soda (75 lbs. nitrogen),	480
6*a*	Dissolved boneblack, } mixed minerals,	320
	Muriate of potash, }	160
10	Mixed minerals, as plot 6*a*,	480
	Sulphate of ammonia (25 lbs. nitrogen),	120
11	Mixed minerals, as plot 6*a*,	480
	Sulphate of ammonia (50 lbs. nitrogen),	240
12	Mixed minerals, as plot 6*a*,	480
	Sulphate of ammonia (75 lbs. nitrogen),	360
00	Nothing,	....
6*b*	Mixed minerals, as plot 6*a*,	480

* Total value, less cost of fertilizer.

Effects upon Yields of Corn. — Between the years 1878 and 1881, a large number of field experiments with corn were conducted, under the supervision of one of us (W. O. A.), upon farms, mostly in New England. The results of these experiments, together with those of a large number of other field experiments with fertilizers, were summarized in a publication by the United States Department of Agriculture, entitled "Results of Field Experiments with various Fertilizers." During the years 1888 and 1889, the Station also carried on some field experiments with this crop. The object of these experiments was to study the effects of different quantities of nitrogen in the fertilizers upon the yields of the crop. The results with regard to the effect upon the yields of shelled corn are briefly summarized on the following page by the averages of the yields from all the experiments in which the conditions were similar.

Four soil tests and eight special nitrogen experiments, comprising 168 plots, were carried out with corn between 1888 and 1896. The results of the nitrogen experiments, with a valuation of the increase in yield following the use of different

gredients and different quantities of nitrogen, as compared with the and the corresponding profits.

Cost of fertilizer.	Yield of hay, 11 per cent. water.	Increase over yield from mineral plots.	Value of increase at $12.00 per ton. Total.	Net.*	Yield of protein per acre.	Plot No.
$	lbs.	lbs.	$	$	lbs.	
....	1,639	....	....	....	117	0
9.21	3,724	1,030	6.18	3.05	289	7
12.33	4,837	2,143	12.86	6.61	420	8
15.46	5,003	2,309	13.85	4.47	480	9
6.08	2,511	....	....	....	214	6*a*
9.83	3,804	1,110	6.66	2.91	285	10
13.58	4,807	2,113	12.68	5.18	410	11
17.33	5,136	2,442	14.65	3.40	487	12
....	2,244	....	....	....	165	00
6.08	2,876	....	....	....	227	6*b*

Summary of field experiments with corn made between 1878 and 1889.

Special nitrogen experiments.	Eighteen experiments, 1878–81.	Four experiments, 1888.	Three experiments, 1889.
	Bush. per acre.	Bush. per acre.	Bush. per acre.
Mixed minerals, ...	43.0	33.4	18.2
Mixed minerals +25 lbs. nitrogen,	48.4	38.2	25.2
Mixed minerals +50 lbs. nitrogen,	48.8	40.2	32.7
Mixed minerals +75 lbs. nitrogen,	49.6	39.2	34.0

quantities of nitrogen, are given in Table 6 on the following page. The figures for yield per acre represent, in each case, the average of the yields of dry matter from all the plots upon which the same kinds and amounts of fertilizers were used. The amounts of dry matter in the yield are calculated from the weight of the crop when it was harvested, upon the assumption

that well dried shelled corn contains 11.1 per cent. (one-ninth) water, and well cured stover 14.3 per cent. (one-seventh) water, these proportions being considered fair averages.

TABLE 6.—*Comparison of yields of corn (grain) from plots upon which different quantities of nitrogen were used.*

Plot No.	Kinds and amounts of fertilizers per acre.		Yield per acre (11.1 % water). Comparative scale, 1,600 lbs. to the inch.	Yield per acre (11.1 % water). lbs.
		lbs.		
0, 00, 000	Nothing,	....		1197
6, 6*a*, 6*b*, 6*c*	Dissolved boneblack,	320		1778
	Muriate of potash,	160		
7, 10, 13	Mixed min. as plot 6,	480		2399
	Nitrogen,	25		
8, 11, 14	Mixed min. as plot 6,	480		2937
	Nitrogen,	50		
9, 12, 15	Mixed min. as plot 6,	480		3004
	Nitrogen,	75		

From this table it appears that the yields of corn increased with the amount of nitrogen in the fertilizer until the nitrogen in the latter reached 50 pounds per acre. When the nitrogen

TABLE 7.—*Yields of corn (grain) and stover by the use of fertilizers the use of mineral fertilizers alone,*

Plot No.	Kinds and amounts of fertilizers per acre.		Cost of fertilizer.
		lbs.	$
0, 00,* 000	Nothing,	....	....
6, 6*a*, 6*b*, 6*c*	Dissolved boneblack, Muriate of potash, mixed minerals,	320 160	6.08
7, 10, 13	Mixed minerals. as plot 6, Nitrogen (in different materials),	480 25	9.53
8, 11, 14	Mixed minerals, as plot 6, Nitrogen (in different materials),	480 50	12.98
9, 12, 15	Mixed minerals, as plot 6, Nitrogen (in different materials),	480 75	16.43

*In these tables the data from the plots having like kinds and amounts of fertilizers have been combined, and averages taken.

was increased to 75 pounds per acre, there was practically no increase in the yield. In this respect the results differ somewhat from the results of similar experiments with the grasses, discussed on preceding pages; for in these experiments there was observed considerable further increase in yield after the nitrogen in the fertiliizers exceeded 50 pounds per acre. This would seem to indicate that, for increasing the weight of the yield, nitrogen is not so effective upon corn as it is upon the grasses.

But while the yield of corn from the use of 75 pounds of nitrogen per acre was little or no greater than that from the use of 50 pounds, the feeding value of the crop from the use of 75 pounds was much higher than that of the crop from the use of 50 pounds. This may be seen by a comparison of the figures in Table 7 herewith.

From this table it appears that although the difference between the yield of grain and stover from the use of 75 pounds of nitrogen per acre and the yield from the use of 50 pounds per acre is relatively quite small, the difference between the yield of protein in the crops from the use of 75 pounds of nitrogen per acre and that in the crop from the use of 50 pounds per acre is considerable.

The valuation of the increase in the yields, with corn at 60 cents per bushel, and stover at $6 a ton, shows very clearly

supplying different quantities of nitrogen, as compared with yields by and the corresponding profits.

Yield of dry matter per acre.		Increase over yield from mineral plots.		Value of increase. (Corn, 60 cents bush., Stover, $6.00 ton.)		Total yield of protein.	Plot No.
Grain—11.1 p. c. Water.	Stover—14.3 p. c. Water.	Grain.	Stover.	Total.	Net.*		
lbs.	lbs.	lbs.	lbs.	$	$	lbs.	
1,197	1,475	......	......	......	......	233	0, 00,* 000,
1,778	2,189	......	......	......	......	289	6, 6*a*, 6*b*, 6*c*
2,399	2,507	621	318	7.61	4.16	395	7, 10, 13
2,937	2,670	1,159	481	13.86	6.96	485	8, 11, 14
3,004	2,767	1,226	578	14.87	4.52	554	9, 12, 15

* Total value less cost of fertilizer.

how much more profitable is the crop from the use of the 50 pounds ration of nitrogen if the crop is to be sold, because, as previously stated, the market value of the crop depends on its weight, and not upon its protein content.

Effects upon Yields of Oats.— Only one soil test and two special nitrogen experiments were made with oats, a very much smaller number than were made with grasses and corn. At the time when these experiments were made the conditions of seasons and soil were not altogether favorable. For these reasons it is thought unadvisable to draw any definite conclusions regarding the effect of nitrogen upon the yields. It may be observed that, in a general way, the results seem to correspond with those with corn and grasses. There was a gradual increase in yield according to the increase in the quantity of nitrogen used, but the profits from the use of nitrogen have been very small. In the next section of the discussion, however, attention is called to the increase in the nitrogen compounds (protein) in the crop as a result of the use of nitrogen in the fertilizer.

The following table gives a comparison of the results of the experiments with oats. The yields per acre are the averages of yields from all the plots having the same kinds and amounts of fertilizer per acre.

TABLE 8.— *Comparison of yields of oats (grain) from plots upon which different quantities of nitrogen were used.*

Plot No.	Kinds and amounts of fertilizers per acre.		Yield per acre (11.1 % water).	
		lbs.	Comparative scale, 400 lbs. to the inch.	lbs.
0, 00, 000	Nothing, . .	....		474
6, 6*a*,	Dissolved boneblack,	320		
6*b*, 6*c*	Muriate of potash, .	160		484
7,	Mixed min. as plot 6,	480		
10, 13	Nitrogen, . .	25		586
8,	Mixed min. as plot 6,	480		
11, 14	Nitrogen, . .	50		633
9,	Mixed min. as plot 6,	480		
12, 15	Nitrogen, . .	75		704

EFFECT OF NITROGEN IN THE FERTILIZER UPON THE PROTEIN OF THE CROP.

In most of the special nitrogen experiments and in a few of the soil test experiments, the effects of nitrogen of the fertilizers upon the composition of the crops have been studied by chemical analysis of samples taken in such a manner that they could be considered representative of the whole crop. The produce of each plot was weighed in the field at the time of harvesting, and the samples were gathered and weighed separately at that time. These samples were put into small bags, and were weighed again just before the analyses were made. From the results of the analyses, together with the weight of the sample and the total weight of the yield, it is possible to estimate not only the percentages of dry matter, nitrogen compounds (protein), and other ingredients, but also the total amounts of the several ingredients per acre. In the following discussion of the effects of nitrogenous fertilizers on the composition of the crop, tables are given showing both the percentage composition and the actual yields per acre calculated from the results of the analyses. The figures in these tables are averages of the results of all the similar experiments for all the years in which they were made. They are the figures given in bold faced type in the corresponding tables in the series at the end of the discussion. The tables there give the details of all the experiments in which analyses have been made; one set of tables gives the percentage composition of the crops analyzed, and the other set gives the yields per acre of nutrients calculated from the percentage composition and the weight of the crop.

Effect upon the Composition of Mixed Grasses.— In the experiments with mixed grasses the samples were taken while the hay was in the windrow, just before it was carted from the field. Large samples, from 12 to 20 pounds, were gathered into coarse sacks by taking small quantities from different parts of the plot. These samples were immediately cut into pieces one or two inches long, and mixed and sub-sampled, the final samples, from 3 to 5 pounds, being carefully weighed. In some instances duplicate, and in others triplicate samples were taken and analyzed separately, in order to prove the accuracy of the sampling. There were occasional slight variations in the composition of the different samples from the same plot, but the results on the whole were very uniform.

In some of these experiments with mixed grasses the results were affected considerably by the varying proportions of clover in the crops from the different plots. In the yields from all the plots to which nitrogen was applied the proportion of clover was so small that the results were not affected materially; but in the yields from plots (*6a* and *6b*) upon which only mineral fertilizers were applied, the proportion of clover was large. Since clover is much richer in protein than the grasses, the percentage of protein in the crops from the mineral plots was proportionately much higher than the percentage in the crops from the nitrogen plots. In comparing the effects of the different fertilizers by the composition of the crops from the different plots this fact should be considered. In 1892, the third year of the experiment, the proportion of nitrogen compounds (protein) in the crop from the mineral plots was so large that it was thought best to make separate analyses of the entire crop and of the grasses. The results of analyses for that year show that the proportion of protein in the entire crop was 10.94 per cent., while in the grasses without the clover it was only 7.19 per cent. Accordingly the results from those plots

TABLE 9.—*Effects of nitrogenous fertilizers*

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.	No. of experiments.
0, 00	Nothing,	......	3
6a, *6b*	Dissolved boneblack,	320	3
	Muriate of potash,	160	
7	Dissolved boneblack,	320	3
	Muriate of potash,	160	
	Nitrate of soda (Nitrogen, 25 lbs.),	160	
8	Dissolved boneblack,	320	3
	Muriate of potash,	160	
	Nitrate of soda (Nitrogen, 50 lbs.),	320	
9	Dissolved boneblack,	320	3
	Muriate of potash,	160	
	Nitrate of soda (Nitrogen, 75 lbs.),	480	
10	Dissolved boneblack,	320	2
	Muriate of potash,	160	
	Sulphate of ammonia (Nitrogen, 25 lbs.),	120	
11	Dissolved boneblack,	320	2
	Muriate of potash,	160	
	Sulphate of ammonia (Nitrogen, 50 lbs.),	240	
12	Dissolved boneblack,	320	2
	Muriate of potash,	160	
	Sulphate of ammonia (Nitrogen, 75 lbs.),	360	

have been omitted in computing the averages of analyses.

The following table shows the average percentages of the various food constituents in the hay of mixed grasses. The figures are those in bold face type in Table 25, page 162, giving details of the analyses of this crop for the three years.

From Table 9 it will be seen that the percentage of protein in the hay crop increased quite uniformly with the increase in the quantities of nitrogen in the fertilizers. For example, in the crops from the plots (6*a* and 6*b*) upon which the mineral fertilizers were used alone, the proportion of protein was 7.83 per cent.; in the crop from plot 7, with 25 pounds of nitrogen per acre in addition to the minerals, the proportion of protein was 7.95 per cent.; in the crop from plot 8, with 50 pounds of nitrogen per acre in the fertilizer, the proportion of protein was 8.46 per cent.; and in the crop from plot 9, to which 75 pounds of nitrogen per acre were applied, the proportion of protein was 9.42 per cent. It will be noticed also that the effect of the nitrogen in the fertilizer upon the proportion of protein in the crop was much the same, whether the nitrogen was supplied in nitrate of soda or in sulphate of ammonia.

upon the composition of hay of mixed grasses.

No. of analyses.	Average percentage of proximate constituents in hay, calculated on water-free substance.					Plot No.
	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
9	7.29	3.67	52.62	31.44	4.98	0, 00
10	7.83	3.44	50.84	32.32	5.57	6*a*, 6*b*
5	7.95	3.62	49.62	33.36	5.45	7
5	8.46	3.65	48.56	34.09	5.24	8
5	9.42	3.68	47.96	33.64	5.30	9
4	7.50	3.60	49.94	33.62	5.34	10
4	8.46	4.29	48.51	33.40	5.34	11
4	9.36	3.82	48.68	32.91	5.23	12

In the following tabulation are shown the total yields of the various food ingredients, and the percentage difference between the yield of dry matter and of protein from the nitrogen plots and the unfertilized plots and that from the mineral plots. The figures given here are the averages given in bold face type in Table 26, page 164

From Table 10 it will be seen that the increase in the total yield of protein was relatively much larger than the increase in the total yield of dry matter. For if the yields from the plots upon which mineral fertilizers only were used be taken as a basis, the relative yields from the plots upon which 25, 50, and 75 pounds of nitrogen were used in addition to the minerals, were respectively as follows: of dry matter, 137, 177, and 188 per cent.; of protein, 127, 188, and 222 per cent. This brings out clearly the fact that the increase in the amount of protein obtained by the use of nitrogenous fertilizers is due not only to the increase in the total yield of the crop, but also to the higher percentages of protein in the composition of the crops from the plots upon which the larger quantities of nitrogen were used. For example, the yield of dry matter from the plot upon which 75 pounds of nitrogen were used was only 11 per cent. greater than the yield from the plot upon which 50 pounds were used; while the percentage of protein in the crop from the former plot was 34 per cent. greater than that in the crop from the latter plot; showing that the nitrogen in the fertilizer had a relatively greater tendency to increase the

TABLE 10. — *Effects of nitrogeneous fertilizers upon yield of prox-*
percentages of yields of dry matter and protein from the

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.	Number of experiments.
0, 00	Nothing,	.....	5
6*a*, 6*b*	Dissolved boneblack, Muriate of potash,	320 160	5
7, 10	Dissolved boneblack, Muriate of potash, Nitrogen,	320 160 25	3
8, 11	Dissolved boneblack, Muriate of potash, Nitrogen,	320 160 50	3
9, 12	Dissolved boneblack, Muriate of potash, Nitrogen,	320 160 75	3

proportion of protein in the crop than it had to increase the total yield of dry matter.

EFFECT UPON THE COMPOSITION OF DIFFERENT SPECIES OF GRASSES.

During the years 1891-98 a series of experiments, amounting to 32 in all, and comprising 114 plots, was carried on upon small plots in the grass garden, as noted on page 189. The plots usually included in the experiments were Nos. 0, 6, 7, and 9, according to the plan of special nitrogen experiments.* The nitrogen was usually supplied in nitrate of soda.

The size of the plots — 2 square rods — was so small that it seemed unadvisable to determine the total yields of the crop, hence the total yields of the food constituents could not be calculated. The percentages of the various food constituents in the crops were determined, however, by analyses of samples taken when the grass was in bloom, or in the early seed stage. The samples were gathered, weighed, cut, and sub-sampled as explained in the sampling of mixed grasses. The result of the experiments as shown by the percentages of protein, fat, etc., found in the crops from the different plots are given beyond in Table 11. The figures of this table are the averages given in bold face type in Table 35, page 190, which gives the analyses of the crops for all the years in which experiments were made.

imate ingredients in hay of mixed grasses, with a comparison of the different plots on the basis of the yield from the mineral plots.

Average yields of proximate constituents of hay per acre.						Percentage of yield on the basis of the yield from the mineral plots.		Plot No.
Dry matter.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Dry matter.	Protein.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	Per cent.	Per cent.	
1,675	121	61	882	527	83	71	62	0, 00
2,368	195	82	1,194	759	138	100	100	6*a*,6*b*
3,240	248	116	1,619	1,082	175	137	127	7, 10
4,202	366	164	2,036	1,411	226	177	188	8, 11
4,458	432	169	2,148	1,470	242	188	222	9, 12

* See page 110.

TABLE 11.—*Effect of nitrogenous fertilizers upon different species of grasses.*

Plot No.	Kinds and amounts of fertilizers per acre, and species of grass.	No. of experiments.	No. of analyses.	Average percentage of proximate constituents in hay, calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
0	*Nothing.*			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
	Timothy,	7	7	7.59	3.31	49.32	33.81	5.97
	Orchard grass,	7	7	8.13	3.98	45.52	34.18	8.19
	Tall meadow fescue grass,	5	5	7.16	3.01	46.41	36.30	7.12
	Tall red top,	2	2	6.89	3.22	52.49	30.46	6.94
	Tall meadow oat grass,	2	2	7.83	3.08	46.07	35.87	7.15
	Brome grass,	2	2	8.13	3.36	50.55	30.39	7.57
	Average of above species,			**7.62**	**3.33**	**48.39**	**33.50**	**7.16**
6	*Dissolved boneblack 320 lbs. Muriate of potash, 160 lbs. No nitrogen.*							
	Timothy,	7	7	7.03	2.94	50.14	33.49	6.40
	Orchard grass,	7	7	7.91	3.72	44.56	34.92	8.89
	Tall meadow fescue grass,	5	5	7.16	2.86	48.74	33.69	7.55
	Tall red top,	2	2	6.60	3.30	52.14	31.06	6.90
	Tall meadow oat grass,	2	2	7.50	3.14	44.99	36.80	7.57
	Brome grass,	2	2	8.17	3.35	50.52	29.34	8.62
	Average of above species,			**7.39**	**3.22**	**48.52**	**33.22**	**7.65**
7	*Dissolved boneblack 320 lbs. Muriate of potash 160 lbs. Nitrate of soda 160 lbs. (Nitrogen, 25 lbs.)*							
	Timothy,	7	7	7.32	3.04	47.88	35.75	6.01
	Orchard grass,	7	7	9.60	4.06	43.27	33.84	9.23
	Tall meadow fescue grass,	6	6	8.30	3.03	47.85	33.45	7.37
	Tall red top,	4	4	7.73	3.15	52.14	30.06	6.92
	Tall meadow oat grass,	3	3	9.97	3.26	44.88	34.81	7.08
	Brome grass,	2	2	8.72	3.39	50.16	30.23	7.50
	Fowl meadow grass,	1	1	12.06	3.28	42.30	32.84	9.52
	Kentucky blue grass,	1	1	12.88	4.04	44.89	31.49	6.70
	Rye grass,	1	1	10.87	2.71	50.79	27.54	8.09
	Average of above species,			**9.72**	**3.33**	**47.13**	**32.22**	**7.60**
9	*Dissolved boneblack 320 lbs. Muriate of patash 160 lbs. Nitrate of soda 480 lbs. (Nitrogen, 75 lbs.)*							
	Timothy,	7	7	9.30	3.26	47.42	34.13	5.89
	Orchard grass,	7	7	12.63	4.52	41.33	32.69	8.83
	Tall meadow fescue grass,	6	6	11.82	3.67	43.96	32.53	8.02
	Tall red top,	4	4	10.40	3.24	50.34	29.33	6.69
	Tall meadow oat grass,	3	3	12.40	3.45	43.11	33.81	7.23
	Brome grass,	2	2	12.97	4.06	43.93	31.54	7.50
	Fowl meadow grass,	1	1	14.87	2.83	42.25	31.65	8.40
	Kentucky blue grass,	1	1	15.44	4.51	43.49	29.62	6.94
	Rye grass,	1	1	12.62	2.92	48.69	27.71	8.06
	Average of above species,			**12.49**	**3.61**	**44.95**	**31.44**	**7.51**

It will be noticed that there are considerable differences in the proportions of protein in the different grasses grown under similar conditions. Of the three grasses, timothy, orchard grass, and meadow fescue, which have been under the experiment longest, orchard grass contained the largest proportion of protein on all the plots, and timothy the smallest on all the plots except the one without fertilizer. As observed on a later page, in the experiments with corn, the crops from the "nothing" plots usually contained a larger proportion of protein than the crop from some of the fertilized plots. This is doubtless accounted for, as in the experiments referred to, by the fact that where no fertilizers are used the crop ripens prematurely, in which case the amount of starch formed is less than in the matured crops, consequently the proportion of protein found is large.

In all cases, the lowest percentage of protein was found in the crops from the plots upon which only mineral fertilizers were used. The average proportion of protein for all the grasses from the mineral plots was 7.39 per cent.; from the plots upon which 25 pounds of nitrogen per acre was used, the average proportion of protein in all the grasses was 9.72 per cent.; from the plots upon which 75 pounds of nitrogen per acre was used the proportion of protein was 12.49 per cent. This means that, on the average, the grasses grown from the plots upon which the one-third ration of nitrogen was used in addition to the minerals were 32 per cent. richer in protein than those grown on the mineral plots; and the grasses grown on the plots upon which the full ration of nitrogen was used in addition to the minerals were nearly 70 per cent. richer in protein than those grown on the mineral plots. These experiments emphasize most forcibly the fact that great improvement can be made in the feeding value of our common grasses by the proper use of nitrogenous fertilizers.

Effect upon the Composition of Corn.— In the experiments with corn, samples of both the grain and the stover were taken separately for analysis. These were gathered at the time when the crop was weighed in the field, just before it was harvested. Large samples of the stover were gathered in much the same way as the samples of hay were taken. Small quantities of stover were taken from different parts of the plot, and were immediately cut into short lengths and sub-sampled. From 10 to 15 pounds of the ears were taken for samples; these were shelled and the weight of shelled corn in the samples was

immediately determined. These determinations served for computing the total yields per acre.

Early in these experiments it was noticed that there was a larger percentage of protein in the corn (seeds) from the plots upon which no fertilizer was used than there was in the corn from the fertilized plots. Later a probable cause of this difference was found in the large proportion of immatured kernels in the seed from the nothing plots; for a series of analyses of corn from several experiments, made so as to compare the

TABLE 12.—*Effects of nitrogenous fertilizers*

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.	No. of analyses.
0, 00, 000	Nothing,	......	23
1 (and A)	Nitrate of soda,	160	9
2 (and B)	Dissolved boneblack,	320	10
3 (and C)	Muriate of potash,	160	10
4 (and D)	Dissolved boneblack, Nitrate of soda,	320 160	9
5 (and E)	Muriate of potash, Nitrate of soda,	160 160	9
6, 6*a*, 6*b*, 6*c* (and F)	Dissolved boneblack, Muriate of potash,	320 160	20
7	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 25 lbs.),	320 160 160	17
8	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 50 lbs.),	320 160 320	10
9	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 75 lbs.),	320 160 480	11
10	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 25 lbs.),	320 160 120	6
11	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 50 lbs.),	320 160 240	6
12	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 75 lbs.),	320 160 360	6
13	Dissolved boneblack, Muriate of potash, Dried blood (Nitrogen, 25 lbs.),	320 160 200	2
14	Dissolved boneblack, Muriate of potash, Dried blood (Nitrogen, 50 lbs.),	320 160 400	2
15	Dissolved boneblack, Muriate af potash, Dried blood (Nitrogen, 75 lbs.),	320 160 600	2

composition of the "good" corn — the hard, merchantable ears — with the "poor" corn — the soft ears and "nubbins,"— showed that in the crops from all the plots the percentage of protein was higher in the "poor" corn than it was in the "good" corn. The reason for the higher percentage of protein in the immatured kernels appears to be that the normal amount of starch was not formed in them, while considerable protein was present, so that the amount of protein was relatively large. The seeds in crops from the nothing plots were

upon composition of corn (grain).

Average percentage of proximate constituents in corn (grain) calculated on water free substance.					Plot No.
Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
11.15	5.43	80.06	1.64	1.72	0, 00, 000
11.92	5.31	79.40	1.69	1.68	1 (and A)
11.38	5.27	79.93	1.70	1.72	2 (and B)
10.49	5.21	80.97	1.68	1.65	3 (and C)
11.98	5.61	79.07	1.61	1.73	4 (and D)
11.11	5.43	80.68	1.59	1.71	5 (and E)
10.13	5.76	80.73	1.66	1.72	6, 6*a*, 6*b*, 6*c* (and F)
10.80	5.77	80.16	1.56	1.71	7
11.50	6.12	78.98	1.64	1.76	8
12.07	6.02	78.46	1.62	1.83	9
10.28	6.37	79.86	1.68	1.81	10
10.60	6.63	79.20	1.68	1.89	11
11.68	6.50	78.30	1.60	1.92	12
9.93	6.33	79.88	1.94	1.92	13
9.34	5.46	81.66	1.85	1.69	14
9.75	5.87	80.56	1.99	1.83	15

largely poor and immature, and, with the small proportions of starch, naturally contained a larger percentage of protein than the crops from the fertilized plots. For this reason the poor corn and "nubbins" were excluded when samples were being taken for analyses.

TABLE 13.—*Effects of nitrogenous*

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.	No. of analyses.
0, 00, 000	Nothing,	......	23
1 (and A)	Nitrate of soda,	160	9
2 (and B)	Dissolved boneblack,	320	10
3 (and C)	Muriate of potash,	160	10
4 (and D)	Dissolved boneblack, Nitrate of soda (Nitrogen 25 lbs.),	320 160	9
5 (and E)	Muriate of potash, Nitrate of soda (Nitrogen 25 lbs.),	160 160	9
6*a*, 6*b*, 6*c*, (and F)	Dissolved boneblack, Muriate of potash,	320 160	20
7	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen 25 lbs.),	320 160 160	17
8	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen 50 lbs.),	320 160 320	10
9	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen 75 lbs.),	320 160 480	11
10	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen 25 lbs.),	320 160 120	6
11	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen 50 lbs.),	320 160 240	6
12	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen 75 lbs.),	320 160 360	6
13	Dissolved boneblack, h. Muriate of potash, Dried blood (Nitrogen 25 lbs.),	320 160 200	2
14	Dissolved boneblack, Muriate of potash, Dried blood (Nitrogen 50 lbs.),	320 160 400	2
15	Dissolved boneblack, Muriate of potash, Dried blood (Nitrogen 75 lbs.),	320 160 600	2

The analyses of the corn (grain) and the stover in these experiments are summarized in Tables 12 and 13. The figures in these tables are the averages given in bold face type in Tables 27 and 28, pages 166 and 171, which give the separate analyses of the several experiments.

fertilizers upon composition of corn stover.

AVERAGE PERCENTAGE OF PROXIMATE CONSTITUENTS IN CORN STOVER, CALCULATED ON WATER-FREE SUBSTANCE.					Plot No.
Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
6.91	1.84	50.76	34.30	6.19	0, 00, 000
7.74	1.96	50.95	33.97	5.38	1 (and A)
7.04	2.03	51.06	33.94	5.93	2 (and B)
6.40	2.15	51.42	33.76	6.27	3 (and C)
7.52	1.89	51.21	33.89	5.49	4 (and D)
6.72	1.99	50.40	34.67	6.22	5 (and E)
5.15	2.10	51.77	34.21	6.77	6*a*, 6*b*, 6*c*, (and F)
5.72	1.94	51.06	34.91	6.37	7
6.52	1.92	50.60	34.50	6.46	8
7.35	1.90	49.91	33.93	6.91	9
5.23	1.94	52.35	33.91	6.57	10
5.04	1.75	52.00	34.77	6.44	11
6.53	1.79	50.53	34.30	6.85	12
4.62	1.80	53.82	33.70	6.06	13
4.10	1.94	53.41	34.81	5.74	14
4.47	1.90	52.93	34.93	5.77	15

From table 12 it will be noticed that the percentage of protein in the grain from the nothing plots was higher than the percentage in the grain from many of the fertilized plots. This was doubtless due, as already suggested, to the large proportion of immatured or partially developed grain from these plots. The percentage of protein was lowest in the crops from the plots (6, 6*a*, 6*b*, 6*c*, F) upon which the mineral fertilizers were used without nitrogen.

By comparing the results of the experiments with mixed minerals alone and those with nitrogen in addition it will be noticed that there was a gradual increase in the proportion of

TABLE 14.—*Effects of nitrogenous fertilizers upon yields of proxi-*
yields from the nothing plot and from the different plots

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.	No. of experiments.	Material.
0, 00, 000.	Nothing,	...	13	Grain
		...	13	Stover
				Total
1 (and A)	Nitrate of soda,	160	7	Grain
		...	7	Stover
				Total
2 (and B)	Dissolved boneblack,	320	8	Grain
		...	8	Stover
				Total
3 (and C)	Muriate of potash,	160	8	Grain
		...	8	Stover
				Total
4 (and D)	Dissolved boneblack,	320	7	Grain
	Nitrate of soda,	160	7	Stover
				Total
5 (and E)	Nitrate of soda,	160	7	Grain
	Muriate of potash,	160	7	Stover
				Total
6, 6*a*, 6*b*, 6*c* (and F)	Dissolved boneblack,	320	13	Grain
	Muriate of potash,	160	13	Stover
				Total
7, 10, 13,	Dissolved boneblack,	320	13	Grain
	Muriate of potash,	160	13	Stover
	Nitrogen,	25	..	Total
8, 11, 14,	Dissolved boneblack,	320	9	Grain
	Muriate of potash,	160	9	Stover
	Nitrogen,	50	..	Total
9, 12, 15,	Dissolved boneblack,	320	9	Grain
	Muriate of potash,	160	9	Stover
	Nitrogen,	75	..	Total

protein in the corn, corresponding to the increase in the amount of nitrogen in the fertilizer. Thus in the experiments with nitrate of soda as the source of nitrogen the proportions of protein were as follows: in the corn from the mineral plots, 10.13 per cent.; from the plots with 25 pounds of nitrogen, 10.80 per cent.; from the plots with 50 pounds of nitrogen, 11.50 per cent.; from the plots with 75 pounds of nitrogen, 12.07 per cent. In the experiments in which sulphate of ammonia was the source of nitrogen there was likewise an increase in the protein with the increase in the nitrogen supplied, but the proportion of protein was not quite so large as in the

mate ingredients of corn (grain) and stover, with a comparison of the having nitrogen with the yield from the mineral plot.

Average yield of proximate constituents of corn (grain) and corn stover per acre.						Percentage of yield on the basis of yield from mineral plot.		Plot No.
Dry matter.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Dry matter.	Protein.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	Per cent.	Per cent.	
1,064	118	61	851	17	18	67	74	0,00,000.
1,264	86	23	641	435	78	67	92	
2,328	**204**	**84**	**1,492**	**452**	**96**	**67**	**81**	
1,123	131	60	897	18	18	71	82	1 (and A)
1,233	91	24	630	421	67	65	99	
2,356	**222**	**84**	**1,527**	**439**	**85**	**68**	**88**	
893	102	48	715	14	15	57	64	2 (and B)
1,168	76	24	598	399	70	62	82	
2,061	**178**	**72**	**1,313**	**413**	**85**	**60**	**70**	
1,093	116	58	883	18	18	69	73	3 (and C)
1,321	84	29	683	444	81	70	90	
2,414	**200**	**87**	**1,566**	**462**	**99**	**70**	**79**	
1,267	153	72	1,002	20	22	80	96	4 (and D)
1,417	105	26	726	482	76	75	113	
2,684	**258**	**98**	**1,728**	**502**	**98**	**78**	**102**	
1,696	187	92	1,361	27	27	107	116	5 (and E)
1,589	102	32	805	555	96	85	110	
3,285	**289**	**124**	**2,166**	**582**	**123**	**95**	**114**	
1,580	160	92	1,274	26	27	100	100	6, 6*a*, 6*b*, 6*c* (and F)
1,876	93	39	980	637	126	100	100	
3,456	**253**	**131**	**2,254**	**663**	**153**	**100**	**100**	
2,132	228	127	1,706	33	37	135	143	
2,149	118	41	1,100	750	139	115	127	7, 10, 13,
4,281	**346**	**168**	**2,806**	**783**	**176**	**124**	**137**	
2,611	290	165	2,068	42	47	165	181	
2,271	136	45	1.157	786	149	121	146	8, 11, 14,
4,882	**426**	**210**	**3,225**	**828**	**196**	**141**	**168**	
2,670	320	166	2,094	42	49	168	200	
2,372	166	43	1,184	814	165	126	178	9, 12, 15,
5,042	**486**	**209**	**3,278**	**856**	**214**	**146**	**192**	

experiments in which nitrate of soda was used. The proportions of protein were, with 25 pounds of nitrogen in sulphate of ammonia, 10.28 per cent.; with 50 pounds of nitrogen, 10.60 per cent.; with 75 pounds of nitrogen, 11.68 per cent. In the experiments in which dried blood was used as a source of nitrogen, the increase in the proportions of protein did not correspond to the quantities of nitrogen used. But as only two such experiments were made, the results should not be compared too closely with those of a larger number of experiments in which other fertilizing materials were used.

TABLE 15.—*Effect of nitrogenous fertilizers*

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.	No. of experiments.
0, 00, 000	Nothing,	......	3
1 (and A)	Nitrate of soda,	160	2
2 (and B)	Dissolved boneblack,	320	2
3 (and C)	Muriate of potash,	160	2
4 (and D)	Dissolved boneblack, Nitrate of soda,	320 160	2
5 (and E)	Muriate of potash, Nitrate of soda,	160 160	2
6, 6*a*, 6*b* (and F)	Dissolved boneblack, Muriate of potash,	320 160	3
7	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 25 lbs.),	320 160 160	2
8	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 50 lbs.),	320 160 320	2
9	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 75 lbs.),	320 160 480	2
10	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 25 lbs.),	320 160 120	1
11	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 50 lbs.),	320 160 240	1
12	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 75 lbs.),	320 160 360	1
13	Dissolved boneblack, Muriate of potash, Dried blood (Nitrogen, 25 lbs.),	320 160 200	2
14	Dissolved boneblack, Muriate of potash, Dried blood (Nitrogen, 50 lbs.),	320 160 400	2
15	Dissolved boneblack, Muriate of potash, Dried blood (Nitrogen, 75 lbs.),	320 160 600	2

In the Table 14 are shown the total and the relative yield per acre of the various food constituents in the corn and stover. The figures in this table are the averages in bold face type in tables 29 and 30, pages 176 and 179, which gives the type in Tables 29 and 30, pages 176 and 179, which give the separate analyses of the several experiments with corn.

From this table it will be observed that the nitrogenous fertilizers had a relatively more marked effect upon the yields of protein than upon the yields of dry matter. Thus, in the grain, the total yield of dry matter with the use of 75 pounds of nitrogen per acre was only slightly larger than the yield from

upon the composition of oats (grain).

No. of analyses.	AVERAGE PERCENTAGE OF PROXIMATE CONSTITUENTS IN OATS (GRAIN), CALCULATED ON WATER-FREE SUBSTANCE.					Plot No.
	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
11	14.22	5.88	65.79	10.74	3.37	0, 00, 000
2	15.08	6.10	66.94	8.56	3.32	1 (and A)
2	13.25	6.04	67.88	9.23	3.60	2 (and B)
2	13.71	6.02	67.79	9.08	3.40	3 (and C)
2	13.68	6.21	68.84	8.15	3.12	4 (and D)
2	14.46	6.15	67.50	8.73	3.17	5 (and E)
8	14.76	6.10	67.03	8.99	3.12	6, 6*a*, 6*b* (and F)
4	14.68	6.01	67.39	8.96	2.96	7
2	16.34	5.79	65.08	9.97	2.82	8
2	16.97	5.68	63.93	10.55	2.87	9
1	13.94	6.05	64.90	12.25	2.86	10
1	15.12	6.14	64.45	11.59	2.70	11
1	15.00	5.86	62.38	13.84	2.92	12
2	15.00	5.84	65.79	10.39	2.98	13
2	14.97	5.81	65.77	10.55	2.90	14
2	15.87	5.95	65.70	9.67	2.81	15

the use of 50 pounds, while the yield of protein with 75 pounds of nitrogen was considerably increased over the yield with 50 pounds. This is shown quite clearly by the last two columns of the tables, which compare the yield from the different nitrogen plots with the yield from the mineral plots. The yield of dry matter with 25 pounds of nitrogen was 35 per cent. greater than that from the mineral plots; the yield with 50 pounds of nitrogen was 65 per cent. greater, while the yield with 75 pounds of nitrogen was only 68 per cent. greater than the yield from the mineral plots; but for the same series of plots the increase in the proportion of protein from the use of nitrogen was 43, 81, and 100 per cent. respectively.

TABLE 16.—*Effects of nitrogenous fertilizers*

Plot No.	Kinds and amounts of fertilizers per acre.		No. of experiments.
		lbs.	
0, 00, 000	Nothing,	......	3
6, 6*a*	Dissolved boneblack,	320	3
6*b*, 6*c*	Muriate of potash,	160	
	Dissolved boneblack,	320	
7	Muriate of potash,	160	2
	Nitrate of soda (Nitrogen, 25 lbs.),	160	
	Dissolved boneblack,	320	
8	Muriate of potash,	160	2
	Nitrate of soda (Nitrogen, 50 lbs),	320	
	Dissolved boneblack,	320	
9	Muriate of potash,	160	2
	Nitrate of soda (Nitrogen, 75 lbs.),	480	
	Dissolved boneblack,	320	
10	Muriate of potash,	160	1
	Sulphate of ammonia (Nitrogen, 25 lbs.),	120	
	Dissolved boneblack,	320	
11	Muriate of potash,	160	1
	Sulphate of ammonia (Nitrogen, 50 lbs.),	240	
	Dissolved boneblack,	320	
12	Muriate of potash,	160	1
	Sulphate of ammonia (Nitrogen, 75 lbs.),	360	
	Dissolved boneblack,	320	
13	Muriate of potash,	160	2
	Dried blood (Nitrogen, 25 lbs.),	200	
	Dissolved boneblack,	320	
14	Muriate of potash,	160	2
	Dried blood (Nitrogen, 50 lbs.),	400	
	Dissolved boneblack,	320	
15	Muriate of potash,	160	2
	Dried blood (Nitrogen, 75 lbs.),	400	

Effect upon the Composition of Oats. — The two special nitrogen experiments with oats comprised 26 plots upon which nitrogen was applied in nitrate of soda, sulphate of ammonia, and dried blood. As in the experiments with corn, samples of both the grain and the straw without the grain were gathered when the crop was harvested, and were carefully prepared for analysis. With the data from these analyses, given in Tables 15 and 16, are included also some of the results of analyses of grain from the soil test experiment. The figures given in these tables are the averages in bold face type in Tables 31 and 32 on pages 182 and 185.

upon composition of oat straw.

No. of analyses.	AVERAGE PERCENTAGE OF PROXIMATE CONSTITUENTS IN OAT STRAW CALCULATED ON WATER-FREE SUBSTANCE.					Plot No.
	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
5	7.39	3.36	47.40	36.84	5.01	0, 00, 000
6	5.04	3.05	46.41	39.95	5.55	6, 6*a* 6*b*, 6*c*
2	4.63	3.16	46.44	40.65	5.12	7
2	4.90	2.95	46.47	40.60	5.08	8
2	6.03	2.97	45.39	40.23	5.38	9
1	5.69	3.60	49.56	36.61	4.54	10
1	6.81	3.38	48.66	37.00	4.15	11
1	7.50	3.18	48.15	37.05	4.12	12
2	4.75	3.01	46.52	40.75	4.97	13
2	4.82	2.95	47.13	40.02	5.08	14
2	5.27	3.04	47.53	39.37	4.79	15

In the discussion of the effect of nitrogenous fertilizers upon the yields of oats, on a previous page, reference was made to the fact that the number of experiments was smaller than that with some of the other crops, and that the conditions of soil and season were unfavorable. For this reason only general conclusions were drawn from the results of the experiments. The same facts should be taken into account in considering the effects of nitrogen of the fertilizers upon the composition of the crop. In a brief discussion of the data of Table 14 it may be observed that, as noticed in experiments with other crops, the proportion of protein in the grain from the "nothing" plots is larger than that in the grain from some of the fertilized plots. In the grain from the mineral plots there was 14.76 per cent. of protein. With 25 pounds of nitrogen per acre in addition to the minerals there was practically the same proportion of protein, 14.68 per cent. With 50 pounds of nitrogen per acre the grain had 16.34 per cent. of protein, a considerable increase, while with 75 pounds of nitrogen per acre it was 16.97 per cent., a still further increase, although not so large as be-

TABLE 17.—*Effects of nitrogenous fertilizers upon yield of proximate centages of yield from the different plots on*

Plot No.	Kinds and amounts of fertilizers per acre.		No. of experiments.	Material.
		lbs.		
			8	Grain
0, 00, 000	Nothing, ...	...	5	Straw
			..	Total
6, 6*a*, 6*b*, 6*c*	Dissolved boneblack, . .	320	6	Grain
	Muriate of potash, . . .	160	6	Straw
			..	Total
7, 10, 13	Dissolved boneblack, . .	320	2	Grain
	Muriate of potash, ...	160	2	Straw
	Nitrogen, ...	25	..	Total
8, 11, 14	Dissolved boneblack, . .	320	2	Grain
	Muriate of potash, ...	160	2	Straw
	Nitrogen, ...	50	..	Total
9, 12, 15	Dissolved boneblack, . .	320	2	Grain
	Muriate of potash, ...	160	2	Straw
	Nitrogen, ...	75	..	Total

fore in proportion to the increase in nitrogen. These are the results from the use of nitrogen in nitrate of soda. There was less gain in the proportion of protein in the grain following the use of nitrogen in sulphate of ammonia, and still less from the use of organic nitrogen in dried blood.

A somewhat similar discussion might apply to the figures in Table 16, showing the effect of nitrogen upon the straw without the grain. From this table, however, it appears that the largest gains and more uniform increase in protein resulted from the use of sulphate of ammonia.

The following table shows the effect of nitrogenous fertilizers upon oats by a comparison of the calculated yields of dry matter and of protein in the crops. The figures given here are the averages in bold face type found in Tables 33 and 34 on pages 187 and 188.

It will be noticed here also, as has been mentioned in the discussion of results with other crops, that the yields of dry matter increased gradually with the increase of the quantities of nitrogen used in the fertilizers; but the protein increased much more rapidly.

ingredients of oats (grain) and oat straw, with a comparison of per- the basis of the yield from the mineral plots.

AVERAGE YIELDS OF PROXIMATE CONSTITUENTS OF OATS (GRAIN) AND OAT STRAW PER ACRE.						PERCENTAGE OF YIELD ON THE BASIS OF THE YIELD FROM THE MINERAL PLOTS.		Plot No.
Dry matter.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Dry matter.	Protein.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	Per cent.	Per cent.	
421	64	25	277	41	15	98	95	
545	33	18	251	213	31	59	75	0, 00, 000
966	**97**	**43**	**528**	**254**	**46**	**72**	**88**	
430	67	27	287	36	13	100	100	
919	44	27	422	373	53	100	100	6, 6*a*, 6*b*, 6*c*
1349	**111**	**54**	**709**	**409**	**66**	**100**	**100**	
521	82	32	344	49	16	121	122	
1264	57	38	580	523	66	138	130	7, 10, 13
1785	**139**	**70**	**924**	**572**	**82**	**132**	**125**	
563	90	33	367	57	16	131	134	
1461	71	42	673	598	77	159	161	8, 11, 14
2024	**161**	**75**	**1040**	**655**	**93**	**150**	**145**	
626	103	36	405	65	18	146	154	
1901	112	54	870	767	99	207	255	9, 12, 15
2527	**215**	**90**	**1275**	**832**	**117**	**187**	**194**	

EFFECT OF NITROGENOUS FERTILIZERS UPON LEGUMES.

During the years 1895-98 inclusive, the Station carried on a series of experiments with several of the legumes, especially cow peas and soy beans. With each crop there were four experiments, comprising 10 plots each, mostly small. Although there were fewer and less extensive experiments with these crops than with cereals and grasses, the results are interesting and important.

Effect upon Yield. — The experiments, on the whole, indicate than the yields of legumes were increased only slightly, if at all, by the use of nitrogenous fertilizers. In many cases the yields with mineral fertilizers were nearly or quite as large as those from the use of nitrogen in addition to the minerals. This was especially noticeable, as seen in Table 18, in the experiments with cow peas grown for fodder, and harvested before or at time of blossom. In these experiments only the plots to which the one-third ration of nitrogen was added yielded crops larger than those from the mineral plots.

The weights of yields per acre given in the following table represent the averages of yields from the plots upon which the same kinds and amounts of fertilizers were used.

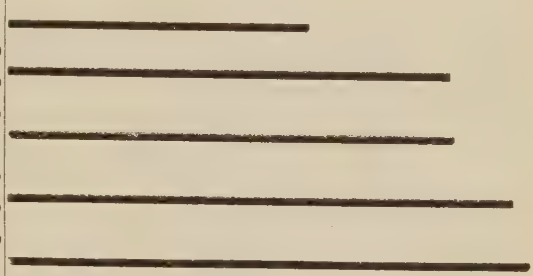
TABLE 18.— *Comparison of yields of cow peas (green plants cut for fodder) from plots upon which different quantities of nitrogen were used.*

Plot No.	Kinds and amounts of fertilizers per acre.		Yield per acre (80 % water). Comparative scale, 10,000 lbs. to the inch.	Yield per acre (80 % water). lbs.
		lbs.		
0, 00	Nothing, . .	....		9660
6*a*, 6*b*	Dissolved boneblack,	320		
	Muriate of potash, .	160		18485
7, 10	Mixed min. as plot 6,	480		
	Nitrogen, . .	25		19265
8, 11	Mixed min. as plot 6,	480		
	Nitrogen, . .	50		18465
9, 12	Mixed min. as plot 6,	480		
	Nitrogen, . .	75		18100

From this table it will be seen that not only was there no increase from the use of nitrogen, but even the yields of the crops from the use of the larger amounts of nitrogen averaged less than those from the use of minerals only.

The following table gives a comparison of the averages of yields of soy beans (seeds) from the different plots upon which the same kinds and amounts of fertilizers were used.

TABLE 19.— *Comparison of yields of soy beans (seeds) from plots upon which different quantities of nitrogen were used.*

Plot No.	Kinds and amounts of fertilizers per acre.		Yield per acre (11 % water). Comparative scale, 450 lbs. to the inch.	Yield per acre (11 % water). lbs.
		lbs.		
0, 00	Nothing,	....		458
6*a*, 6*b*	Dissolved boneblack,	320		
	Muriate of potash,	160		680
7, 10	Mixed min. as plot 6,	480		
	Nitrogen,	25		696
8, 11	Mixed min. as plot 6,	480		
	Nitrogen,	50		784
9, 12	Mixed min. as plot 6,	480		
	Nitrogen,	75		794

From this table it is noticed that there was some slight increase in the yield of the soy bean crop following the use of nitrogenous fertilizers, but it was not sufficient to make their use at all economical for this crop.

Soy beans and cow peas are not commonly found in our markets; consequently it is difficult to estimate their market value. For this reason, and because of the small size of the plots and the small number of experiments conducted, it has been thought best not to attempt to estimate the financial gains.

Effect upon the Composition. — The composition of the legumes was determined by analyses of samples carefully gathered in much the same manner as described in the sampling of other crops. Only the seeds of the soy beans were analyzed, because, as already explained (page 116), it was found impracticable to take representative samples of the whole plant. Although the total number of analyses of these crops is not large, yet the results of all of them appear to indicate that nitrogen added to the fertilizer does not tend to increase very largely the proportion of nitrogen compounds (protein) found in the crop. This is shown in the following tables, which give the average composition of the cow pea fodder and of the soy beans from all plots having uniform quantities of mineral fertilizers with different quantities of nitrogen. The figures in these tables are the averages given in bold face type in Tables 36 and 38, pages 197 and 201.

TABLE 20.—*Effect of nitrogenous fertilizers upon the*

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.	No. of experiments.
0, 00, 000	Nothing,	......	5
6*a*, 6*b*	Dissolved boneblack, Muriate of potash,	320 160	6
7	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 25 lbs.),	320 160 160	6
8	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 50 lbs.),	320 160 320	4
9	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 75 lbs.),	320 160 480	6
10	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 25 lbs.),	320 160 120	4
11	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 50 lbs.),	320 160 240	4
12	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 75 lbs.),	320 160 360	4

TABLE 21.—*Effect of nitrogenous fertilizers*

Plot No.	Kinds and amounts of fertilizers per acre.	lbs.	No. of experiments.
0, 00	Nothing,	......	3
6*a*, 6*b*	Dissolved boneblack, Muriate of potash,	320 160	4
7	Dissolved boneblack, Muriate of potash, Nitrate of Soda (Nitrogen, 25 lbs.),	320 160 160	4
8	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 50 lbs.),	320 160 320	3
9	Dissolved boneblack, Muriate of potash, Nitrate of soda (Nitrogen, 75 lbs.),	320 160 480	4
10	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 25 lbs.),	320 160 120	3
11	Dissolved boneblack, Muriate potash, Sulphate of ammonia (Nitrogen, 50 lbs.)	320 160 240	3
12	Dissolved boneblack, Muriate of potash, Sulphate of ammonia (Nitrogen, 75 lbs),	320 160 360	3

composition of cow peas (plants grown for fodder).

No. of analyses.	Average percentage of proximate constituents in cow pea fodder, calculated on water-free substance.					Plot No.
	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
12	18.38	3.57	44.67	21.76	11.62	0, 00, 000
10	18.37	3.18	44.32	23.47	10.96	6*a*, 6*b*
7	17.90	3.41	44.27	23.25	11.17	7
4	18.20	3.11	44.82	24.11	9.79	8
6	18.96	3.72	44.55	22.11	10.66	9
4	18.17	3.24	44.17	23.63	10.79	10
4	17.18	3.29	46.01	22.90	10.62	11
4	19.32	3.05	43.48	22.96	11.19	12

upon the composition of soy bean seed.

No. of analyses.	Average percentage of proximate constituents in soy bean seed, calculated on water-free substance.					Plot No.
	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
6	39.96	19.00	29.32	4.50	7.22	0, 00
7	39.30	20.01	30.77	3.92	6.00	6*a*, 6*b*
4	39.87	19.75	30.43	3.94	6.00	7
3	40.69	20.00	29.28	4.20	5.83	8
4	41.61	19.56	29.35	3.87	5.61	9
3	39 99	20.59	29.76	3.88	5.78	10
3	40.73	20.54	29.57	3.57	5.59	11
3	41.33	20.16	28.38	3.87	6.26	12

From the results given in these tables it would seem that there is very little relationship between the quantities of nitrogen used in the fertilizer and the percentages of protein found in the crop. The percentage of protein in the crops from the plots upon which only mineral fertilizers were used is about as high as that in the crops from the plots to which nitrogen was applied in addition to the minerals. In the case of the cow pea as cut for fodder (see Table 20) the only noticeable increase in the percentage of protein was found in the crops from the plots upon which 75 pounds of nitrogen per acre was used. In the case of the soy beans, however (see Table 21), it appears that the nitrogen of the fertilizer had a little more effect upon the composition of the crop; for there is a difference in the percentage of protein in the crops from the different plots, a small increase corresponding fairly regularly to the increase in the quantities of nitrogen in the fertilizers used. In the crops from the plots upon which the full ration of nitrogen was applied in nitrate of soda the percentage of protein was 2.3 per cent. higher than that in the crops from the plots upon which only the minerals were used. Similarly, a small gain in the protein of this crop may be noticed when sulphate of ammonia is the source of nitrogen in the fertilizer.

The total yields of dry matter and of protein per acre in the cow pea fodder and soy beans are given in the following tables. The weights of the yields given are the averages in bold face type found in Tables 37 and 39, pages 199 and 203.

TABLE 22.—*Effects of nitrogenous fertilizers upon cow peas grown for fodder, with a comparison of percentages of yields of dry matter and protein from the different plots on the basis of the yield from the mineral plots.*

Plot No.	Kinds and amounts of fertilizers per acre.		No. of experiments.	Average yields of proximate constituents of cow pea fodder per acre.						Percentage of yield on basis of the yield from mineral plots.	
				Dry matter.	Protein.	Fat.	Nitrogen-free extract.	Fiber.	Ash.	Dry matter.	Protein.
		lbs.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	Per ct.	Per ct.
0, 00	Nothing,	.....	4	1,932	344	68	880	429	211	52	52
6*a*, 6*b*	Dissolved boneblack, Muriate of potash, No nitrogen,	320 160 ...	4	3,697	666	113	1,661	873	384	100	100
7, 10	Dissolved boneblack, Muriate of potash, Nitrogen,	320 160 25	4	3,853	666	118	1,768	916	385	104	100
8, 11	Dissolved boneblack, Muriate of potash, Nitrogen,	320 160 50	4	3,693	675	118	1,640	873	387	100	101
9, 12	Dissolved boneblack, Muriate of potash, Nitrogen,	320 160 75	4	3,620	665	119	1,648	817	371	98	100

TABLE 23.—*Effects of nitrogenous fertilizers upon soy beans (seeds), with a comparison of the yields of dry matter and protein from the different plots on the basis of the yield from the mineral plots.*

Plot No.	Kinds and amounts of fertilizers per acre.		No. of experiments.	Average yields of proximate constituents of soy bean (seeds) per acre.						Percentage of yield on basis of yield from mineral plots.	
				Dry matter.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Dry matter.	Protein.
		lbs.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	Per cent.	Per cent.
0, 00	Nothing,	.....	3	412	165	80	117	16	34	67	68
6*a*, 6*b*	Dissolved boneblack, Muriate of potash, No nitrogen,	320 160 ...	3	612	241	128	183	22	38	100	100
7, 10	Dissolved boneblack, Muriate of potash, Nitrogen,	320 160 25	3	626	252	130	184	22	38	102	105
8, 11	Dissolved boneblack, Muriate of potash, Nitrogen,	320 160 50	3	706	288	147	206	24	41	115	120
9, 12	Dissolved boneblack, Muriate of potash, Nitrogen,	320 160 50	3	715	297	146	203	26	43	117	123

From the tables it will be seen that the yields of both dry matter and protein in the cow pea fodder remain nearly uniform without regard to the quantities of nitrogen in the fertilizer used. This is shown most plainly by the columns giving the percentage of yields. The basis taken for comparison and for computation of percentages is the yield from the plots supplied with the mineral fertilizers alone. Taking these yields at 100 per cent., the largest yield of cow pea fodder from any of the nitrogen plots reaches only 104 per cent. for dry matter and 101 per cent. for protein; while the largest yield of soy beans was 117 per cent. of dry matter and 123 per cent. of protein.

The results of the experiments with legumes are in striking contrast to those of experiments with grasses. This is shown clearly by the table on page 158, comparing results in dry matter and protein from experiments with all the crops. The maximum increase in yield from the plots where the largest ration of nitrogen was used, over that from plots where only mineral fertilizers were used, was 17 per cent. of dry matter and 23 per cent. of protein in the soy beans, compared with 88 per cent. of dry matter and 122 per cent of protein in the grasses.

The contrast thus shown between the grasses and the legumes in regard to the effect of nitrogenous fertilizers is of economical importance to the farmer. It is greatly to his advantage to know that nitrogenous fertilizers applied to grasses like timothy, red top, etc., increase not only the total yield of crop, but also, in a relatively greater proportion, the percentage of protein in the crop; while the same kinds and amounts of nitrogenous fertilizers have little or no effect upon either the total yield or the percentage of protein in such crops as clover, alfalfa, vetches, cow pea, soy beans, etc.

On the other hand, the fact that the legumes, as shown by the experiments reported, can be grown advantageously by the use of no other fertilizers than the mixed minerals is also of very great practical importance. These crops are rich in protein, but the nitrogen for its formation they take largely from the air, instead of drawing heavily upon that in the soil, as do the grasses and cereals. Thus by growing the leguminous crops, and by practising a judicious system of rotation, the farmer may increase greatly the amount of protein produced upon the farm, and at the same time conserve the fertility of the soil.

SUMMARY OF EXPERIMENTS AND RESULTS.

Summary. — The experiments on the effects of nitrogenous fertilizers were undertaken for the study of two problems: first, the relative economy of the use of nitrogen in different amounts and combinations in the production of grasses, grains, and legumes; and second, the effect of the nitrogen of the fertilizer on the proportion of nitrogen compounds (protein) in the crop. These experiments have been made on the Station farm, and on a large number of farms throughout the State.

The experiments were of two kinds, called "special nitrogen" and "soil test" experiments. The number of soil test experiments in which chemical analyses of samples were made was quite limited, but the results have been incorporated with those from the special nitrogen experiments whenever it was thought that they would add to the general value of the work.

The experiments here reported consisted, first, of special nitrogen field experiments upon mixed grasses, corn, oats, cow peas, and soy beans; and second, of a modified form of the same class of experiments, conducted on small plots with distinct species of grasses; and third, of a small number of soil test experiments with corn and oats.

The special nitrogen field experiments were conducted upon a series of plots, all of which, except two without any fertilizer, were treated with uniform quantities of mineral fertilizer (phosphoric acid and potash). In addition to the mineral fertilizer different materials supplying nitrogen were used in varying amounts, sufficient to furnish 25, 50, and 75 pounds of nitrogen per acre. The materials in which nitrogen was supplied were nitrate of soda and sulphate of ammonia, and in a few cases dried blood. The plots were generally from one-tenth to one-twentieth acre each. All in a given experiment were of the same size.

The experiments on distinct species of grasses were conducted, in most cases, upon plots one-eightieth of an acre in size, and were similar to the special nitrogen field experiments except that lack of space prevented the use of so many plots. The plots used were those receiving no fertilizer, those receiving mineral fertilizers only, and those receiving mineral fertilizers plus nitrogen at the rate of 25 and 75 pounds per acre.

The soil test experiments were undertaken primarily to study the fertilizer requirements of different soils and crops. They were generally laid out on a series of plots of from one-

tenth to one-twentieth acre each, to which were applied the various fertilizer ingredients (nitrogen, phosphoric acid, and potash) singly, two by two, and all three together.

Results. — The experiments in which dried blood was used as a source of nitrogen were so few that no deductions from the yield of the crop can be made concerning the economy in using this material for fertilizer. From the experiments with the other materials supplying nitrogen it would appear that there was more advantage in the use of nitrate of soda than in the use of sulphate of ammonia. This was due rather to the higher cost of the sulphate of ammonia than to its lower efficiency as a fertilizer, although slightly larger yields were usually obtained on the plots where nitrate of soda was used.

In the experiments with mixed grasses it was found that nitrogen in the fertilizer increased very considerably the yield of hay, and also to a marked degree the proportion of nitrogen compounds (protein) in the crop, especially where the larger quantities of nitrogen were used. Thus the use of nitrogen proved to be economical as affecting the amounts and consequently the commercial value of the crop, and still further so affecting the feeding value. On the whole, the most economical returns were made by the plots containing nitrate of soda at the rate of 320 pounds (nitrogen 50 pounds) per acre.

In the experiments with corn the efficiency of nitrogen in the fertilizer in increasing the yield of the crop was not so marked as it was in the experiments with mixed grasses. While in the experiment on the grasses the yield from the use of 75 pounds of nitrogen per acre was considerably greater than the yield from the use of 50 pounds, in the experiments on corn the average yield with 75 pounds was very little more than with the use of 50 pounds of nitrogen per acre. In these experiments the most economical results were from the plots upon which 160 pounds of nitrate of soda (25 pounds of nitrogen) were used. These results seem to indicate that, in the use of fertilizers on corn, under such conditions as those in these experiments, the most economical amount of nitrogen ranges between 25 and 40 pounds per acre (equal to 160 to 250 pounds of nitrate of soda). In all the experiments with corn the proportion of the nitrogen compounds (protein) in both the seed and the stover was considerably larger in the crops from the plots upon which nitrogen was used in addition to the mixed minerals than it was in the crops from the plots upon which only mineral fertilizers were used. In these experi-

ments also the use of nitrate of soda was more economical than that of sulphate of ammonia.

The number of experiments with oats was not sufficient to warrant deductions as to the quantities or kinds of fertilizer materials supplying nitrogen that may be used on that crop with most economy. In all the experiments in which nitrogen was used the yield was markedly increased. In general, the results are similar to those obtained with mixed grasses and corn. The effect of the nitrogen on the composition of the crop, especially of the seed, was quite marked. This was most noticeable on the plots to which nitrate of soda was applied.

The effect of the nitrogen of the fertilizer in increasing the nitrogen compounds (protein) of the crop was more noticeable in the experiments with distinct species of grasses than in any of the other experiments. The average composition of all the kinds of grasses experimented upon gives the following percentages: in grasses from plots having only mineral fertilizers (phosphoric acid and potash), 7.4 per cent. protein; in those from plots having nitrogen at the rate of 25 pounds per acre, in addition to the minerals, 9.7 per cent. protein; and in those from plots having nitrogen at the rate of 75 pounds per acre, in addition to the minerals, 12.5 per cent. protein. This means that a ton of the crop from the plots upon which nitrogen was used at the rate of 75 pounds per acre would contain (60 per cent.) 120 pounds more protein than would a ton of the crop from the plot upon which minerals only were used, showing that the nitrogen of the fertilizer greatly increased the value of the crop independently of its effect upon the yield.

With soy beans (seed) and cow peas (plants grown for fodder) the results were very different from those with cereals and grasses. The nitrogenous fertilizers had very little effect upon either the yield or the composition of the crops. That is to say, these legumes showed very little increase, either in yield or in the percentages of protein, resulting from the use of nitrogen in the fertilizer. The yield of dry matter in the crops from the nitrogen plots was but very little larger than in the crops from the mineral plots. In protein also the yield was but slightly greater in the crops from the nitrogen plots.

A comparison between relative yields of dry matter and of protein in the grasses and corn on the one hand, and in cow peas and soy beans on the other, is given in the following table, taking the yield from the mineral plots as a basis.

TABLE 24.— *Yields of dry matter and protein in grasses and corn by the use of different quantities of nitrogen, compared with yields in cow peas and soy beans by the use of the same quantities. In these calculations yield with mineral fertilizer only is taken at 100.*

Fertilizers.	Grasses.		Corn, grain.		Cow peas, green plant.		Soy beans, seeds.	
	Dry matter.	Protein.	Dry matter.	Protein.	Dry matter.	Protein.	Dry matter.	Protein.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Minerals only, . . .	100	100	100	100	100	100	100	100
Minerals + nitrogen 25 lbs.,	137	127	135	143	104	100	102	105
Minerals + nitrogen 50 lbs.,	177	188	165	181	100	101	115	120
Minerals + nitrogen 75 lbs.,	188	222	168	200	98	100	117	123

PRACTICAL DEDUCTIONS.

One of the clearest deductions that may be made from the results of these experiments is that, in the use of nitrogenous fertilizers, great care should be taken to adapt the fertilizers used to the crop grown.

The true grasses, like timothy and red top, make most of their growth during a short period of time in the early part of the season. For this reason the best results in yield and in feeding value depend upon the amount of nitrogen that is immediately available for the growing plant; and it is important that whatever nitrogen is supplied in fertilizers should be in materials, like sulphate of ammonia or nitrate of soda, in which it is readily available. Corn, however, while it is also a species of grass and a vigorous feeder, grows more slowly, and is able to obtain considerable nitrogen from the organic matter decaying in the soil during the later part of the season. It makes some gain from the nitrogen supplied in nitrogenous fertilizers, but it does not respond so vigorously to their use as do the true grasses.

On the other hand, the legumes, such as clovers, soy beans, and cow peas, make very little gain, either in yield or in feeding value, from the use of nitrogen in the fertilizer. They make considerable increase in yield when the mineral fertilizers are used. A large part of their nitrogen they take from the air.

In brief, the experiments teach that, (1) the grasses are greatly benefited by the proper use of nitrogenous fertilizers;

(2) the legumes are benefited largely and chiefly by the use of mineral fertilizers; (3) the legumes, which take much of their nitrogen from the air and leave a great deal behind in their roots and stubble and otherwise in the soil for the use of plants that come after them, should be grown in rotation with crops of the grass family which feed heavily upon the readily available nitrogen of the soil; (4) all crops need the mineral fertilizers. The cereals and grasses respond also to nitrogen.

DETAILED DATA OF THE EXPERIMENTS.

The following Tables, 25 to 39, give in detail the data from the experiments with the various crops grown upon plots treated with different kinds and amounts of fertilizers. The composition of each crop (except the pure species of grasses) is given in two tables, both based upon the water-free substance in the crop. The first table shows the percentage of protein (nitrogen x 6.25), fat, nitrogen-free extract, and ash contained in the crop at the time of harvesting, as determined by chemical analysis; and the second table shows the yields of nutrients per acre, computed by the use of the percentage composition.

The grasses were generally harvested at, or soon after, the time of blossoming, and in the case of field crops, were sampled immediately after the total weight of the crop was determined. Large samples of 5 to 8 pounds of hay, or about 10 to 35 pounds of grass, were taken for the main sample. These were cut in a feed-cutter into pieces an inch or so in length and well mixed. From the material thus mixed were taken sub-samples of 500 to 1,000 grams of hay, and 1,500 to 4,000 grams of green crop, which were partially dried in a steam dryer. At the laboratory these were ground into a finely pulverized condition preparatory to taking the final sample for analysis.

In much the same way the corn stover was sampled immediately after the corn was husked and the crop weighed. A large sample, about one peck, of the merchantable corn (ears) was selected from each plot, the corn was shelled off at once and the proportion of grain determined. The grain was then partially dried, and later finely ground, and the samples stored in tightly sealed jars until the analyses could be made.

The oats were sampled at the time of threshing and weighing the crop, the sample of straw being taken as in sampling hay. Of the grain a sample of 2 to 6 pounds was taken immediately after the crop was weighed, and, after being partially dried, was finely ground and the samples stored in sealed jars until they could be analyzed.

The cow peas were sampled just after the crop was cut for silage, in much the same way as the grasses, and the seed of the soy beans were sampled in about the same way as oats, just after the crop was thrashed and weighed.

The analyses are published mainly to show the effect of nitrogen in the fertilizer on the proportion of nitrogen compounds (protein) in the crop. The chief point of interest in a study of them is found in a comparison of the protein in the crops from the plots to which only mineral fertilizers were applied, with the protein in the crops from the plots to which nitrogen also was applied at the rate of 25, 50, and 75 pounds per acre. (Compare plots 6, 6*a*, 6*b* with plots 7, 8, 9, and 10, 11, 12.)

The data in the tables giving the yields of nutrients per acre were obtained as follows: The weight of the crop at harvest multiplied by the percentage of water-free substance in the crop, as shown by drying the small samples in hydrogen gas at 100° C. (212° F.), gives as a product the total amounts of nutrients, or water-free substance, per acre. The amount of water-free substance multiplied by the percentages of nutrients contained in it, as shown by analysis, gives the yields of these ingredients per acre.

Explanation of Tables 25 and 26. — The analyses given in Table 25 are those of samples of mixed grasses from experiments conducted by the Station during the years 1890, 1891, and 1892. The general plan of the experiment included a series of plots upon all of which, except the "nothing" plots, was applied uniform quantities of phosphoric acid and potash, and, in addition, different quantities of nitrogen. The nitrogen was applied upon three of the plots in nitrate of soda, and upon three others in sulphate of ammonia. The kinds and quantities of the different fertilizers used are given in the second column of the tables. The third column shows the kind of the experiment. In determining the proportions of food constituents, *i. e.*, protein, fat, etc., in the crop, the differences in the proportions of water are left out of account by basing the calculations upon the amount of dry matter or water-free substance in the crop.

It will be noticed that there are more analyses of crops from the plots with nitrate of soda than of crops from the plots with sulphate of ammonia. This is due to the fact that the experiments upon the former plots extended through three years, while those upon the latter extended through only two.

Table 26 gives the total yields of water-free substance and the computed yields of food constituents. The yields of water-free substance per acre were determined from the weights of the crop when harvested and the percentage of water found in the sample when dried. The yields of protein, fat, etc., were calculated by multiplying the weight of the yield of water-free substance per acre, given in this table, by the percentages of protein, fat, etc., found by analysis of the samples from the corresponding plots as given in Table 25.

In all the experiments the results from plots with like kinds and quantities of fertilizers are averaged, as shown by figures in bold face type. These averages are the values which are given in the summary Tables 9 and 10, on pages 130 and 132 in the discussion of results.

TABLE 25.—*Effects of nitrogenous fertilizers upon hay of mixed grasses.*

[The details of the analyses may be found in the Reports of the Station for the years in which the several experiments were made or for the succeeding year.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of hay calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.			Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct	Pr. ct.
1890	Plot 0, ...	Spe. nitrogen	804	7.25	3.72	52.56	31.45	5.02
1890	Duplicate of last, .	"	805	7.06	3.68	53.27	31.16	4.83
1890	00, ...	"	806	7.13	3.61	52.75	31.59	4.92
1890	Duplicate of last, .	"	807	7.50	4.28	51.99	31.16	5.07
1890	0, Duplicate of above,	"	824	7.63	3.50	52.75	31.07	5.05
1890	00, Duplicate of above,	"	825	7.56	3.76	52.27	31.20	5.21
1891	0, ...	"	990	6.44	3.38	54.58	31.06	4.54
1891	00, ...	"	991	7.31	3.94	52.01	31.72	5.02
1892	0, ...	"	1,054	7.69	3.17	51.43	32.57	5.14
	Average,		. . .	7.29	3.67	52.62	31.44	4.98
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen, —							
1890	Plot 6*a*, ...	Spe. nitrogen	808	8.00	3.07	50.12	32.95	5.86
1890	Duplicate of last, .	"	809	7.94	2.98	50.12	33.24	5.72
1890	6*b*, ...	"	810	7.94	3.31	51.07	32.01	5.67
1890	Duplicate of last, .	"	811	8.31	3.52	50.23	32.10	5.84
1890	6*a*, Duplicate of above,	"	826	8.75	3.57	49.65	32.16	5.87
1890	6*b*, Duplicate of above,	"	827	8.44	3.94	49.46	32.16	6.00
1891	6*a*, ...	"	992	6.63	3.45	53.63	31.10	5.19
1891	6*b*, ...	"	993	7.31	4.03	51.13	31.84	5.69
1892	6*a* (total crop), . .	"	*1,055	10.94	3.19	47.25	32.00	6.62
1892	6*a* (grasses only), .	"	1,059	7.19	3.09	52.04	33.35	4.33
	Average,		. . . .	7.83	3.44	50.84	32.32	5 57
	Dis. Boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1890	Plot 7, ...	Spe. nitrogen	812	8.38	3.77	48.38	33.87	5.60
1890	Duplicate of last, .	"	813	8.56	3.49	48.64	33.64	5.67
1890	Duplicate of last, .	"	828	8.19	3.85	49.48	33.11	5.37
1891	7, ...	"	994	6.94	3.66	52.28	32.01	5.11
1892	7, ...	"	1,056	7.69	3.34	49.29	34.16	5.52
	Average,		. . . .	7.95	3.62	49.62	33.36	5.45
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 320 lbs. (nitrogen, 50 lbs.)							
1890	Plot 8, ...	Spe. nitrogen	814	8.19	3.56	48.50	34.58	5.17
1890	Duplicate of last, .	"	815	8.19	3.27	48.58	34.93	5.03
1890	Duplicate of last, .	"	829	7.88	3.65	49.00	34.32	5.15
1891	8, ...	"	995	8.75	4.08	49.15	32.69	5.33
1892	8, ...	"	1,057	9.31	3.69	47.55	33.93	5.52
	Average,		. . . .	8.46	3.65	48.56	34.09	5.24

* Omitted from average.

TABLE 25.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of hay calculated on water free substance.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)			Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.
1890	Plot 9, ...	Spe. nitrogen	816	9.00	3.23	47.99	34.70	5.08
1890	Duplicate of last, .	"	817	9.31	3.13	47.83	34.48	5.25
1890	Duplicate of last, .	"	830	9.25	4.16	46.98	34.48	5.13
1891	9, ...	"	996	9.00	4.29	49.98	31.40	5.33
1892	9, ...	"	1,058	10.56	3.57	47.00	33.14	5.73
	Average,		....	9.42	3.68	47.96	33.64	5.30
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Sul. of amm., 120 lbs. (nitrogen, 25 lbs.)							
1890	Plot 10, ...	Spe. nitrogen	818	7.50	3.41	48.99	34.82	5.28
1890	Duplicate of last, .	"	819	7.50	3.28	50.12	33.79	5.31
1890	Duplicate of last, .	"	831	7.63	3.85	49.05	34.00	5.47
1891	10, ...	"	997	7.38	3.86	51.61	31.87	5.28
	Average,		....	7.50	3.60	49.94	33.62	5.34
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Sul. of Amm., 240 lbs. (nitrogen, 50 lbs.)							
1890	Plot 11, ...	Spe. nitrogen	820	8.31	5.90	46.49	34.07	5.23
1890	Duplicate of last, .	"	821	8.20	3.53	48.69	34.57	5.01
1890	Duplicate of last, .	"	832	8.56	3.64	49.14	33.31	5.75
1891	11, ...	"	998	8.75	4.08	49.73	31.66	5.78
	Average,		....	8.46	4.29	48.51	33.40	5.34
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Sul. of Amm., 360 lbs. (nitrogen, 75 lbs.)							
1890	Plot 12, ...	Spe. nitrogen	822	9.13	3.33	48.21	34.23	5.10
1890	Duplicate of last, .	"	823	9.50	3.44	48.82	33.07	5.17
1890	Duplicate of last, .	"	833	8.88	4.20	48.14	33.75	5.03
1891	12, ...	"	999	9.94	4.30	49.55	30.61	5.60
	Average,		....	9.36	3.82	48 68	32.91	5.23

TABLE 26.—*Effects of nitrogenous fertlizers upon hay of mixed grasses.*

[The details of the experiments may be found in the Reports of the Station for the years in which the several experiments were made or for the year following.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Yields of dry matter and nutrients in hay per acre.					
			Water free substance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
	Nothing.							
1890	Plot 0,	Spe. nitrogen	1,707	125	62	902	533	85
1890	00,	"	2,505	185	97	1,311	785	127
1891	0,	"	1,531	99	52	836	475	69
1891	00,	"	1,483	108	58	772	470	75
1892	0,	"	1,147	88	36	590	374	59
	Average,		**1,675**	**121**	**61**	**882**	**527**	**83**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen, —							
1890	Plot 6*a*,	Spe. nitrogen	2,989	246	96	1,493	980	174
1890	6*b*,	"	3,204	264	115	1,610	1,028	187
1891	6*a*,	"	1,956	130	67	1,049	608	102
1891	6*b*,	"	1,908	139	77	976	607	109
1892	6*a*,	"	1,782	195	57	842	570	118
	Average,		**2,368**	**195**	**82**	**1,194**	**759**	**138**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen (different forms), 25 lbs.							
1890	Plots 7, 10,	Spe. nitrogen	4,190	334	151	2,058	1,419	228
1891	7, 10,	"	2,813	201	106	1,462	898	146
1892	7,	"	2,716	209	91	1,338	928	150
	Average,		**3,240**	**248**	**116**	**1,619**	**1,082**	**175**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen (different forms), 50 lbs.							
1890	Plots 8, 11,	Spe. nitrogen	5,151	424	202	2,492	1,767	266
1891	8, 11,	"	3,735	327	152	1,846	1,203	207
1892	8,	"	3,720	346	137	1,769	1,263	205
	Average,		**4,202**	**366**	**164**	**2,036**	**1,411**	**226**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen (different forms), 75 lbs.							
1890	Plots 9, 12,	Spe. nitrogen	5,370	493	193	2,576	1,832	276
1891	9, 12,	"	3,777	357	162	1,880	1,176	207
1892	9,	"	4,227	446	151	1,987	1,401	242
	Average,		**4,458**	**432**	**169**	**2,148**	**1,470**	**242**

Explanation of Tables 27, 28, 29, 30. — Tables 27 and 28 show the analyses of samples of corn (grain) and stover respectively, taken in experiments extending over a period of nine years, although most of the experiments on a single field were not repeated more than once or twice. Two kinds of experiments were made; (1) soil tests, conducted primarily to study the deficiencies of soils in regard to the chief fertilizer ingredients; and (2) special nitrogen experiments conducted for the purpose of studying the effects of the nitrogenous fertilizers on the yield and the composition of the crop. In some cases the soil tests were a part of the special nitrogen experiments. In many of the soil tests samples for analysis have been taken, and the results averaged with those of the special nitrogen tests, from plots upon which the fertilizers applied were alike in kind and amount. (See plots A and 1, B and 2, G and 7.) The percentages of food constituents in the corn and in the stover are calculated upon the basis of water-free substance in the crop when it was harvested. The averages, given in bold face type, are the values used in the summary Tables 12 and 13, pages 136 and 138 in the discussion of results.

Tables 29 and 30 give the total yields of water-free substance and of the various food constituents in corn and stover from the same series of experiments. The amounts of water-free substance were determined by the weight of the corn and stover, and the percentage of water they contained, at the time when they were harvested. The amounts of food constituents were estimated from the water-free substance and composition shown by analyses. The averages given in bold face type in these tables are found in the summary Table 14, page 140 in the discussion.

TABLE 27.—*Effects of nitrogenous fertlizers upon corn (grain, flint varieties).*

[The details of the analyses may be found in the Reports of the Station for the years in which the several experiments were made or for the succeeding year.]

Year.	Plot no. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	PERCENTAGE COMPOSITION OF CORN CALCULATED ON WATER-FREE SUBSTANCE.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1888	Plots 0 and 00, . .	Soil test	603	11.13	5.13	80.48	1.55	1.71
1888	0 and 00, . .	Spe. nitrogen	629	13.06	5.65	78.34	1.42	1.53
1888	0 and 00, . .	"	639	11.56	5.63	79.48	1.55	1.78
1888	0 and 00, . .	"	659	12.06	5.32	79.38	1.63	1.61
1888	0 and 00, . .	"	669	11.56	5.25	79.86	1.74	1.59
1889	0 and 00, . .	"	695	12.50	5.30	78.44	1.88	1.88
1889	0 and 00, . .	"	727	11.44	6.01	78.25	2.25	2.05
1889	0 and 00, . .	Soil test	753	11.06	5.27	79.80	1.98	1.89
1890	0, ...	"	873	10.56	5.50	80.89	1.52	1.53
1890	Duplicate of last,	"	875	10.31	5.13	81.39	1.54	1.63
1890	00, . . .	"	877	10.75	5.22	80.94	1.46	1.63
1890	Duplicate of last,	"	879	10.19	4.91	81.85	1.52	1.53
1890	0, ...	"	913	12.38	4.84	78.72	2.14	1.92
1890	00, ...	"	917	11.13	4.84	80.29	1.96	1.78
1891	0, ...	Spe. nitrogen	1,030	11.00	5.69	80.32	1.32	1.67
1895	0, ...	"	1,547	10.37	5.85	80.37	1.65	1.76
1895	00, ...	"	1,548	10.91	5.26	80.81	1.36	1.66
1895	0, ...	"	1,567	10.42	6.43	79.59	1.69	1.89
1895	00, ...	"	1,568	10.56	5.44	80.95	1.44	1.61
1896	0, ...	"	1,756	9.90	5.81	80.60	2.08	1.61
1896	00, ...	"	1,757	10.22	5.84	80.20	1.92	1.82
1896	0, ...	"	1,766	11.14	5.46	80.14	1.47	1.79
1896	00, ...	"	1,767	11.21	5.20	80.27	1.61	1.71
	Average,		....	**11.15**	**5.43**	**80.06**	**1.64**	**1.72**
	Nitrate of soda, 160 lbs.							
1888	Plot A, ...	Soil test	605	10.94	5.12	80.85	1.50	1.59
1888	1, ...	Spe. nitrogen	627	13.25	5.34	78.31	1.50	1.60
1888	1, ...	"	641	11.63	6.00	78.97	1.66	1.74
1888	1, ...	"	671	12.25	5.24	79.11	1.74	1.66
1889	1, ...	"	697	12.75	5.11	77.95	2.27	1.92
1889	A, ...	Soil test	755	11.94	5.81	78.09	2.11	2.05
1890	A, ...	"	881	12.06	5.09	80.02	1.38	1.45
1890	Duplicate of last,	"	883	10.63	5.04	81.35	1.48	1.50
1890	A, ...	"	921	11.81	5.06	79.91	1.58	1.64
	Average,		....	**11.92**	**5.31**	**79.40**	**1.69**	**1.68**
	Dissolved boneblack, 320 lbs.							
1888	Plot B, ...	Soil test	607	11.38	5.33	80.27	1.41	1.61
1888	2, ...	Spe. nitrogen	625	13.38	5.60	78.00	1.39	1.63
1888	2, ...	"	643	11.06	5.58	79.96	1.55	1.85
1888	2, ...	"	673	11.63	5.55	79.67	1.72	1.63
1889	2, ...	"	699	13.25	5.30	77.38	2.06	2.01
1889	2, ...	"	729	10.44	5.18	80.49	2.05	1.84
1889	B, ...	Soil test	757	11.06	5.23	79.85	2.08	1.78
1890	B, ...	"	885	10.31	5.28	81.28	1.46	1.67
1890	Duplicate of last,	"	887	10.38	5.08	81.59	1.42	1.53
1890	B, ...	"	925	10.94	4.73	80.78	1.86	1.69
	Average,		....	**11.38**	**5.27**	**79.93**	**1.70**	**1.72**

TABLE 27.— CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	PERCENTAGE COMPOSITION OF CORN CALCULATED ON WATER-FREE SUBSTANCE. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Muriate of potash, 160 lbs.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1888	Plot C, ...	Soil test	609	9.88	5.25	81.66	1.55	1.66
1888	3, ...	Spe. nitrogen	623	13.06	5.23	78.34	1.66	1.71
1888	3, ...	"	645	10.25	5.57	80.95	1.49	1.74
1888	3, ...	"	675	10.88	5.08	80.86	1.63	1.55
1889	3, ...	"	701	10.19	5.65	80.43	1.84	1.89
1889	3, ...	"	731	10.38	4.93	80.90	2.06	1.73
1889	C, ...	Soil test	759	11.06	5.17	80.07	1.88	1.82
1890	C, ...	"	889	11.19	5.19	80.73	1.39	1.50
1890	Duplicate of last,	"	891	9.56	5.00	82.52	1.40	1.52
1890	C, ...	"	929	8.44	5.01	83.23	1.89	1.43
	Average,		....	**10.49**	**5.21**	**80.97**	**1.68**	**1.65**
	Dis. boneblack, 320 lbs.							
	Nitrate of soda, 160 lbs.							
1888	Plot D, ...	Soil test	611	11.94	5.78	79.05	1.52	1.71
1888	4, ...	Spe. nitrogen	621	13.38	6.34	77.09	1.47	1.72
1888	4, ...	"	647	12.44	5.60	78.45	1.69	1.82
1888	4, ...	"	677	12.00	5.36	79.23	1.57	1.84
1889	4, ...	"	703	12.44	6.87	77.12	1.58	1.99
1889	D, ...	Soil test	761	11.44	4.99	79.83	1.91	1.83
1890	D, ...	"	893	11.31	5.33	80.40	1.44	1.52
1890	Duplicate of last,	"	895	11.56	5.17	80.26	1.47	1.54
1890	D, ...	"	933	11.31	5.05	80.21	1.81	1.62
	Average,		....	**11.98**	**5.61**	**79.07**	**1.61**	**1.73**
	Muriate of potash, 160 lbs.							
	Nitrate of soda, 160 lbs.							
1888	Plot E, ...	Soil test	613	12.94	5.43	78.43	1.52	1.68
1888	5, ...	Spe. nitrogen	619	13.13	5.64	78.19	1.54	1.50
1888	5, ...	"	649	11.63	5.60	79.38	1.65	1.74
1888	5, ...	"	679	10.50	5.54	81.01	1.35	1.60
1889	5, ...	"	705	10.44	6.26	79.33	1.86	2.11
1889	E, ...	Soil test	763	12.00	5.19	78.69	2.00	2.12
1890	E, ...	"	897	10.19	5.04	81.74	1.37	1.66
1890	Duplicate of last,	"	899	10.19	5.06	81.84	1.38	1.53
1890	E, ...	"	937	9.00	5.11	82.80	1.65	1.44
	Average,		....	**11.11**	**5.43**	**80.16**	**1.59**	**1.71**
	Dis. boneblack, 320 lbs.							
	Muriate ef potash, 160 lbs.							
	Nitrogen, —							
1888	Plot F, ...	Soil test	615	10.75	5.35	80.62	1.63	1.65
1888	6, 6*a*, 6*b*, . .	Spe. nitrogen	631	12.50	5.55	78.88	1.53	1.54
1888	6, 6*a*, 6*b*, 6*c*, .	"	651	9.88	5.64	81.16	1.56	1.76
1888	6, 6*a*, 6*b*, 6*c*, .	"	661	11.44	5.57	79.72	1.62	1.55
1888	6, 6*a*, 6*b*, 6*c*, .	"	681	10.94	5.21	80.61	1.62	1.62
1889	6, 6*a*, 6*b*, 6*c*, .	"	725	9.69	6.27	80.52	1.69	1.83
1889	6, 6*a*, ...	"	733	10.88	6.78	77.95	2.22	2.17
1889	F, ...	Soil test	765	11.06	4.73	80.64	1.77	1.80
1890	F, ...	"	901	10.38	5.29	81.39	1.33	1.61
1890	Duplicate of last,	"	903	10.06	5.41	81.52	1.39	1.62

TABLE 27.— CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of corn calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, etc.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1890	Plot F, . . .	Soil test	941	8.25	5.26	83.24	1.72	1.53
1891	6, . . .	Spe. nitrogen	1,031	10.88	5.85	80.19	1.44	1.64
1895	6*a*, . . .	"	1,549	8.97	6.49	80.92	1.88	1.74
1895	6*b*, . . .	"	1,550	8.68	5.88	81.57	2.20	1.67
1895	6*a*, . . .	"	1,569	9.81	6.57	80.35	1.46	1.81
1895	6*b*, . . .	"	1,570	10.42	6.54	79.60	1.55	1.89
1896	6*a*, . . .	"	1,758	9.31	6.21	80.66	2.03	1.79
1896	6*b*, . . .	"	1,759	9.38	5.88	81.01	2.03	1.70
1896	6*a*, . . .	"	1,768	9.58	5.35	82.00	1.33	1.74
1896	6*b*, . . .	"	1,769	9.82	5.34	82.03	1.21	1.60
	Average,		....	**10.13**	**5.76**	**80.73**	**1.66**	**1.72**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1888	Plot G, . . .	Soil test	617	11.69	5.26	79.70	1.59	1.76
1888	7, 10, 13,* . .	Spe. nitrogen	633	12.44	5.70	78.84	1.44	1.58
1888	7, 10, 13,* . .	"	653	10.19	5.42	81.29	1.47	1.63
1888	7, 10, 13,* . .	"	663	12.69	5.45	78.44	1.81	1.61
1888	7, 10, 13,* . .	"	683	12.69	6.15	77.90	1.49	1.77
1889	7, . . .	"	707	10.50	7.22	78.23	1.99	2.06
1889	7, . . .	"	735	10.50	5.78	79.90	2.05	1.77
1889	G, . . .	Soil test	767	10.94	5 04	80.51	1.84	1.57
1890	G, . . .	"	905	11.52	5.32	80.25	1.33	1.60
1890	Duplicate of last,	"	907	11.25	5.31	80.46	1.44	1.54
1890	G, . . .	"	945	9.06	5.39	82.56	1.55	1.44
1890	Ga, . . .	"	949	8.69	5.04	83.28	1.48	1.51
1891	7, . . .	Spe. nitrogen	1,032	11.00	5.92	80.23	1.19	1.66
1895	7, . . .	"	1,551	10.26	6.03	80.51	1.42	1.78
1895	7, . . .	"	1,571	10.62	7.67	77.89	1.67	2.15
1896	7, . . .	"	1,760	9.34	5.60	82.16	1.36	1.54
1896	7, . . .	"	1,770	10.17	5.89	80.58	1.35	2.01
	Average,		....	**10.80**	**5.77**	**80.16**	**1.56**	**1.71**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitr. of soda, 320 lbs. (nitrogen 50 lbs.)							
1888	Plots 8, 11, 14,* . .	Spe. nitrogen	635	13.25	5.72	77.97	1.46	1.60
1888	8, 11, 14,* . .	"	655	10.50	5.36	80.94	1.59	1.61
1888	8, 11, 14,* . .	"	665	12.19	5.66	78.90	1.67	1.58
1888	8, 11, 14,* . .	"	685	11.75	5.65	79.39	1.50	1.71
1889	8, . . .	"	709	11.25	7.12	77.60	1.96	2.07
1889	8, . . .	"	737	11.00	5.77	79.35	2.11	1.77
1895	8, . . .	"	1,552	10.92	6.45	79.34	1.49	1.80
1895	8, . . .	"	1,572	11.87	6.94	77.77	1.53	1.89
1896	8, . . .	"	1,761	10.76	5.85	80.31	1.39	1.69
1896	8, . . .	"	1,771	11.40	6.73	78.23	1.74	1.90
	Average,		....	**11.50**	**6.12**	**78.98**	**1.64**	**1.76**

* Combined samples (three forms of nitrogen).

TABLE 27.— CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of corn calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1888	Plots 9, 12, 15,* .	Spe. nitrogen	637	14.38	5.67	76.89	1.37	1.69
1888	9, 12, 15,* .	"	657	11.75	5.63	79.40	1.52	1.70
1888	9, 12, 15,* .	"	667	13.19	5.59	77.93	1.69	1.60
1888	9, 12, 15,* .	"	687	12.00	5.10	79.74	1.53	1.63
1889	9, . . .	"	711	9.88	7.03	79.14	1.83	2.12
1889	9, . . .	"	739	11.19	6.14	78.15	2.24	2.28
1891	9, . . .	"	1,033	11.88	6.25	78.77	1.41	1.69
1895	9, . . .	"	1,553	11.93	5.80	78.97	1.59	1.71
1895	9, . . .	"	1,573	12.48	7.05	76.83	1.56	2.08
1896	9, . . .	"	1,762	11.68	6.28	78.81	1.46	1.77
1896	9, . . .	"	1,772	12.46	5.67	78.46	1.60	1.81
	Average,		....	**12.07**	**6.02**	**78.46**	**1.62**	**1.83**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Sul. of ammo., 120 lbs. (nitrogen, 25 lbs.)							
1889	Plot 10, . . .	Spe. nitrogen	713	9.00	6.48	80.94	1.74	1.84
1889	10, . . .	"	743	10.31	5.80	79.56	2.41	1.92
1895	10, . . .	"	1,554	10.27	6.69	79.86	1.53	1.65
1895	10, . . .	"	1,574	11.00	6.91	78.61	1.53	1.95
1896	10, . . .	"	1,763	10.20	6.79	79.56	1.60	1.85
1896	10, . . .	"	1,773	10.91	5.56	80.62	1.26	1.65
	Average,		....	**10.28**	**6.37**	**79.86**	**1.68**	**1.81**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Sul. of ammo., 240 lbs. (nitrogen, 50 lbs.)							
1889	Plot 11, . . .	Spe. nitrogen	715	8.94	6.78	80.85	1.64	1.79
1889	11, . . .	"	743	12.06	5.92	77.82	2.27	1.93
1895	11, . . .	"	1,555	10.37	6.12	80.40	1.50	1.61
1895	11, . . .	"	1,575	11.42	7.43	77.57	1.54	2.04
1896	11, . . .	"	1,764	9.87	6.98	79.64	1.58	1.93
1896	11, . . .	"	1,774	10.96	6.55	78.94	1.54	2.01
	Average,		....	**10.60**	**6.63**	**79.20**	**1.68**	**1.89**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Sul. of ammo., 360 lbs. (nitrogen, 75 lbs.)							
1889	Plot 12, . . .	Spe. nitrogen	717	11.13	6.18	78.96	1.85	1.88
1889	12, . . .	"	745	11.50	6.38	78.05	2.07	2.00
1895	12, . . .	"	1,556	12.11	6.67	77.60	1.57	1.85
1895	12, . . .	"	1,576	12.19	7.05	77.25	1.49	2.02
1896	12, . . .	"	1,765	11.13	6.16	79.62	1.31	1.78
1896	12, . . .	"	1,775	12.04	6.36	78.34	1.30	1.96
	Average,		...	**11.68**	**6.50**	**78.30**	**1.60**	**1.92**

* Combined samples (three forms of nitrogen).

TABLE 27.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	PERCENTAGE COMPOSITION OF CORN CALCULATED ON WATER-FREE SUBSTANCE.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 200 lbs. (nitrogen, 25 lbs.)			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1889	Plot 13, . . .	Spe. nitrogen	719	9.81	6.94	79.39	1.88	1.98
1889	13, . . .	"	747	10.06	5.71	80.38	2.00	1.85
	Average,		....	**9.93**	**6.33**	**79.88**	**1.94**	**1.92**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 400 lbs. (nitrogen, 50 lbs.)							
1889	Plot 14, . . .	Spe. nitrogen	721	9.06	5.93	81.37	1.84	1.80
1889	14, . . .	"	749	6.63	4.99	81.94	1.86	1.58
	Average,		....	**9.34**	**5.46**	**81.66**	**1.85**	**1.69**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 600 lbs. (nitrogen, 75 lbs.)							
1889	Plot 15, . . .	Spe. nitrogen	723	9.19	6.09	80.98	1.89	1.85
1889	15, . . .	"	751	10.31	5.65	80.15	2.08	1.81
	Average,		....	**9.75**	**5.87**	**80.56**	**1.99**	**1.83**

TABLE 28.—*Effects of nitrogenous fertilizers upon corn stover (flint varieties).*

[The details of the analyses may be found in the Reports of the Station for the years in which the several experiments were made or for the succeeding year.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Labratory No.	PERCENTAGE COMPOSITION OF CORN STOVER CALCULATED ON WATER-FREE SUBSTANCE. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1888	Plots o and oo, . .	Soil test	604	4.69	1.64	50.66	37.25	5.76
1888	o and oo, . .	Spe. nitrogen	630	10.06	2.57	48.33	31.09	7.95
1888	o and oo, . .	"	640	8.25	2.44	52.37	30.74	6.20
1888	o and oo, . .	"	660	7.13	1.59	48.25	35.87	7.16
1888	o and oo, . .	"	670	8.94	1.89	50.67	31.37	7.13
1889	o and oo, . .	"	694	7.94	1.77	48.49	36.34	5.46
1889	o and oo, . .	"	726	6.44	2.07	51.85	33.91	5.73
1889	o and oo, . .	Soil test	752	7.25	2.09	52.35	32.72	5.59
1890	o, ...	"	872	4.06	1.52	50.06	39.16	5.20
1890	Duplicate of last,	"	874	4.63	1.66	50.49	37.43	5.79
1890	oo, ...	"	876	5.75	1.66	50.33	37.49	4.77
1890	Duplicate of last,	"	878	5.44	1.78	49.99	37.20	8.59
1890	o, ...	"	912	10.00	1.83	52.19	31.21	4.77
1890	oo, ...	"	916	8.88	1.66	52.05	32.42	4.99
1891	o, ...	Spe. nitrogen	1,017	7.00	2.59	51.90	30.90	7.61
1895	o, ...	"	1,537	5.82	1.54	51.92	35.43	5.29
1895	oo, ...	"	1,538	5.91	1.75	52.08	36.23	4.03
1895	o, ...	"	1,557	5.60	1.75	54.98	31.82	5.85
1895	oo, ...	"	1,558	7.10	1.77	51.68	31.74	7.71
1896	o, ...	"	1,736	7 75	1.24	52.10	31.27	7.64
1896	oo, ...	"	1,737	6.70	1.98	46.23	37.72	7.37
1896	o, ...	"	1,746	7.33	1.79	48.63	34.59	7.66
1896	oo, ...	"	1,747	6.37	1.66	49.87	34.90	7.20
	Average,			**6.91**	**1.84**	**50.76**	**34.30**	**6.19**
	Nitrate of soda, 160 lbs.							
1888	Plot A, . . .	Soil test	606	5.63	2.12	50.27	36.66	5.32
1888	1, ...	Spe. nitrogen	628	9.75	2.37	49.20	31.75	6.93
1888	1, ...	"	642	7.06	1.76	52.79	32.76	5.63
1888	1, ...	"	672	8.81	1.97	49.85	33.90	5.47
1889	1, ...	"	696	9.63	1.69	54.59	29.69	4.40
1889	A, ...	Soil test	754	8.56	1.86	51.02	32.97	5.59
1890	A, ...	"	880	5.06	2.08	49.77	38.26	4.83
1890	Duplicate of last,	"	882	5.56	2.16	49.50	37.58	5.20
1890	A, ...	"	920	9.63	1.62	51.59	32.14	5.02
	Average,			**7.74**	**1.96**	**50.95**	**33.97**	**5.38**
	Dissolved boneblack, 320 lbs.							
1888	Plot B,, . . .	Soil test	608	4.50	1.81	51.21	36.70	5.78
1888	2, ...	Spe. nitrogen	626	9.44	2.27	47.91	32.20	8.18
1888	2, ...	"	644	6.94	2.31	52.43	31.83	6.59
1888	2, ...	"	674	8.94	2.27	49.96	32.35	6.48
1889	2, ...	"	698	9.38	1.68	52.97	30.73	5.24
1889	2, ...	"	728	4.69	2.03	53.10	34.81	5.37
1889	B, ...	Soil test	756	7.69	2.03	51.76	33.00	5.52
1890	B, ...	"	884	4.69	2.57	49.75	37.29	5.70
1890	Duplicate of last,	"	886	4.06	1.88	51.06	38.10	4.90
1890	B, ...	"	924	10.06	1.55	50.47	32.42	5.50
	Average,			**7.04**	**2.03**	**51.06**	**33.94**	**5.93**

TABLE 28.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of corn stover calculated on water-free substance.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Muriate of potash, 160 lbs.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1888	Plot C, . . .	Soil test	610	4.31	2.05	50.97	36.77	5.90
1888	3, . . .	Spe. nitrogen	624	10.19	2.19	49.53	31.20	6.89
1888	3, . . .	"	646	7.13	2.16	50.62	32.46	7.63
1888	3, . . .	"	676	7.81	2.06	49.96	32.32	7.85
1889	3, . . .	"	700	5.63	1.94	56.99	29.97	5.47
1889	3, . . .	"	730	4.44	1.82	55.71	32.58	5.45
1889	C, . . .	Soil test	758	7.06	2.02	51.78	33.22	5.92
1890	C, . . .	"	888	4.75	2.33	48.98	37.54	6.40
1890	Duplicate of last,	"	890	4.13	1.78	49.62	38.63	5.84
1890	C, . . .	"	928	8.56	3.12	50.04	32.88	5.40
	Average,			6.40	2.15	51.42	33.76	6.27
	Dissolved boneblack, 320 lbs. *Nitrate of soda, 160 lbs.*							
1888	Plot D, . . .	Soil test	612	5.44	1.90	51.40	36.12	5.14
1888	4, . . .	Spe. nitrogen	622	8.88	2.07	49.89	32.76	6.40
1888	4, . . .	"	648	8.94	1.75	51.42	32.12	5.77
1888	4, . . .	"	678	8.31	1.92	49.90	33.27	6.60
1889	4, . . .	"	702	9.31	1.71	53.57	30.25	5.16
1889	D, . . .	Soil test	760	7.88	2.10	51.32	32.98	5.72
1890	D, . . .	"	892	4.88	1.93	51.19	36.75	5.25
1890	Duplicate of last,	"	894	4.94	2.09	51.46	36.84	4.67
1890	D, . . .	"	932	9.06	1.53	50.78	33.91	4.72
	Average,			7.52	1.89	51.21	33.89	5.49
	Muriate of potash, 160 lbs. *Nitrate of soda, 160 lbs.*							
1888	Plot E, . . .	Soil test	614	5.50	1.79	49.63	37.05	6.03
1888	5, . . .	Spe. nitrogen	620	9.31	2.16	47.68	33.15	7.70
1888	5, . . .	"	650	7.69	2.13	51.11	32.84	6.23
1888	5, . . .	"	680	8.75	2.10	49.88	31.86	7.41
1889	5, . . .	"	704	5.50	1.73	52.51	34.28	5.98
1889	E, . . .	Soil test	762	8.31	1.86	51.47	32.83	5.53
1890	E, . . .	"	896	4.75	2.20	49.49	37.72	5.84
1890	Duplicate of last,	"	898	4.88	1.89	49.78	37.51	5.94
1890	E, . . .	"	936	5.75	2.09	52.04	34.80	5.32
	Average,			6.72	1.99	50.40	34.67	6.22
	Dissolved boneblack, 320 lbs. *Muriate of potash, 160 lbs.* *Nitrogen,—*							
1888	Plot F, . . .	Soil test	616	4.38	1.75	51.16	36.55	6.16
1888	6, 6*a*, 6*b*, . .	Spe. nitrogen	632	8.75	2.03	47.65	33.48	8.09
1888	6, 6*a*, 6*b*, 6*c*, .	"	652	6.13	2.61	51.55	32.48	7.23
1888	6, 6*a*, 6*b*, 6*c*, .	"	662	7.06	1.61	48.56	35.22	7.55
1888	6, 6*a*, 6*b*, 6*c*, .	"	682	6.06	2.09	51.36	33.92	6.57
1889	6, 6*a*, 6*b*, 6*c*, .	"	724	4.63	2.19	56.66	31.13	5.39
1889	6, 6*a*, . .	"	732	5.06	1.73	54.95	31.83	6.43
1889	F, . . .	Soil test	764	6.56	2.52	52.17	32.29	6.46
1890	F, . . .	"	900	4.19	2.02	50.13	37.38	6.28
1890	Duplicate of last,	"	902	3.88	1.82	50.61	37.82	5.87

TABLE 28. — CONTINUED.

Year.	Plot No. and kind and amount of fertilizers per acre.	Kind of experiment.	Laboratory No.	Percentage composition of corn stover calculated on water free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dissolved boneblack, etc.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1890	Plot F,	Soil test	940	4.25	2.67	55.20	32.78	5.10
1891	6,	Spe. nitrogen	1,018	5.56	2.33	51.71	31.64	8.76
1895	6*a*,	"	1,539	4.72	2.24	53.73	33.65	5.66
1895	6*b*,	"	1,540	4.62	2.08	50.82	37.05	5.43
1895	6*a*,	"	1,559	3.40	1.68	55.05	33.57	6.30
1895	6*b*,	"	1,560	3.90	2.42	54.23	32.63	6.82
1896	6*a*,	"	1,738	5.37	2.11	49.12	36.13	7.27
1896	6*b*,	"	1,739	5 07	2.27	50.11	35.24	7.31
1896	6*a*,	"	1,748	4.77	2.11	51.24	33.43	8.45
1896	6*b*,	"	1,749	4.52	1.75	49.46	36.03	8.24
	Average,			**5.15**	**2.10**	**51.77**	**34.21**	**6.77**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrate of soda, 160 lbs. (nitrogen, 25 lbs.)							
1888	Plot G,	Soil test	618	4.81	1.55	51.21	36.31	6.12
1888	7, 10, 13,*	Spe. nitrogen	634	8.06	2.18	49.12	33.10	7.54
1888	7, 10, 13,*	"	654	6.19	2.02	51.50	32.82	7.47
1888	7, 10, 13,*	"	664	8.19	1.84	46.73	35.66	7.58
1888	7, 10, 13,*	"	684	7.38	2.11	52.41	32.53	5.57
1889	7,	"	706	4.75	1.72	53.63	34.22	5.68
1889	7,	"	734	4.94	1.77	54.04	33.90	5.35
1889	G,	Soil test	766	8.69	2.01	49.62	33.74	5.94
1890	G,	"	904	4.88	2.21	50.59	36.73	5.59
1890	Duplicate of last,	"	906	4.69	2.04	50.83	36.24	6.20
1890	G,	"	944	5.13	1.89	51.79	35.33	5.86
1890	G*a*,	"	948	4.74	1.85	51.81	35.63	5.97
1891	7,	Spe. nitrogen	1,019	6.56	1.99	49.32	33.92	8.21
1895	7,	"	1,541	4.77	1.74	53.24	35.10	5.15
1895	7,	"	1,561	3.34	1.82	54.18	35.30	5.36
1896	7,	"	1,740	5.28	2.00	46.22	39.67	6.83
1896	7,	"	1,750	4.89	2.17	51.70	33.30	7.94
	Average,			**5.72**	**1.94**	**51.06**	**34.91**	**6.37**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrate of soda, 320 lbs. (nitrogen, 50 lbs.)							
1888	Plots 8, 11, 14,*	Spe. nitrogen	636	9.31	2.00	47.30	32.96	8.43
1888	8, 11, 14,*	"	656	5.88	1.92	51.71	34.08	6.41
1888	8, 11, 14,*	"	666	7.94	1.91	48.33	34.87	6.95
1888	8, 11, 14,*	"	686	7.44	1.97	51.87	33.09	5.63
1889	8,	"	708	5.19	1.70	52.45	35.24	5.42
1889	8,	"	736	5.25	1.85	52.94	34.17	5.79
1895	8,	"	1,542	5.95	2.13	51.38	34.98	5.56
1895	8,	"	1,562	5.34	1.85	54.33	32.67	5.81
1896	8,	"	1,741	6.91	1.85	46.80	37.08	7.36
1896	8,	"	1,751	5.97	1.99	48.85	35.91	7.28
	Average,			**6.52**	**1.92**	**50.60**	**34.50**	**6.46**

* Combined samples (three forms of nitrogen).

TABLE 28. — CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	PERCENTAGE COMPOSITION OF CORN STOVER CALCULATED ON WATER-FREE SUBSTANCE. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrate of soda, 480 lbs. (nitrogen, 75 lbs.)			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1888	Plots 9, 12, 15,* .	Spe. nitrogen	638	11.31	0.96	46.90	30.95	8.88
1888	9, 12, 15,* .	"	658	7.31	1.88	48.58	35.60	6.63
1888	9, 12, 15,* .	"	668	8.69	1.42	45.87	34.49	9.53
1888	9, 12, 15,* .	"	688	7.53	1.88	51.55	32.83	6.21
1889	9, . . .	"	710	5.63	1.83	53.21	34.11	5.22
1889	9, . . .	"	738	5.56	2.09	51.76	34.98	5.61
1891	9, . . .	"	1,020	8.06	2.36	49.59	31.67	8.32
1895	9, . . .	"	1,543	4.61	1.86	51.92	36.81	4.80
1895	9, . . .	"	1,563	6.86	1.70	51.97	33.56	5.91
1896	9, . . .	"	1,742	7.04	1.92	46.80	36.69	7.55
1896	9, . . .	"	1,752	8.30	1.95	50.84	31.59	7.32
	Average,			**7.35**	**1.90**	**49.91**	**33.93**	**6.91**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Sul. of ammonia, 120 lbs. (nitrogen, 25 lbs.)							
1889	Plot 10, . . .	Spe. nitrogen	712	5.06	1.85	55.58	32.14	5.37
1889	10, . . .	"	740	5.36	1.79	52.34	34.24	6.27
1895	10, . . .	"	1,544	6.38	1.81	52.24	34.37	5.20
1895	10, . . .	"	1,564	4.42	1.70	54.56	32.71	6.55
1896	10, . . .	"	1,743	5.45	2.27	48.66	36.24	7.38
1896	10, . . .	"	1,753	4.70	2.20	50.70	33.71	8.69
	Average,			**5.23**	**1.94**	**52.35**	**33.91**	**6.57**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Sul. of ammonia, 240 lbs. (nitrogen, 50 lbs.)							
1889	Plot 11, . . .	Spe. nitrogen	714	4.06	1.75	53.60	34.79	5.80
1889	11, . . .	"	742	5.13	1.38	51.03	36.85	5.61
1895	11, . . .	"	1,545	4.42	1.72	54.15	35.04	4.67
1895	11, . . .	"	1,565	4.54	1.73	54.24	32.68	6.81
1896	11, . . .	"	1,744	6.25	1.86	49.13	35.51	7.25
1896	11, . . .	"	1,754	5.81	2.08	49.85	33.75	8.51
	Average,			**5.04**	**1.75**	**52.00**	**34.77**	**6.44**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Sul. of ammonia, 360 lbs. (nitrogen, 75 lbs.)							
1889	Plot 12, . . .	Spe. nitrogen	716	4.94	1.32	51.62	36.50	5.62
1889	12, . . .	"	744	6.44	2.02	51.05	34.75	5.74
1895	12, . . .	"	1,546	5.75	1.71	52.09	35.02	5.43
1895	12, . . .	"	1,566	6.50	1.93	53.46	28.93	9.18
1896	12, . . .	"	1,745	8.54	1.94	48.65	33.27	7.60
1896	12, . . .	"	1,755	6.99	1.81	46.31	37.36	7.53
	Average,			**6.53**	**1.79**	**50.53**	**34.30**	**6.85**

* Combined samples (three forms of nitrogen).

TABLE 28. — CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of corn stover calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 200 lbs. (nitrogen, 25 lbs.)			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1889	Plot 13, . . .	Spe. nitrogen	718	4.56	1.76	54.74	33.31	5.63
1889	13, . . .	"	746	4.69	1.84	52.89	34.09	6.49
	Average,			4.62	1.80	53.82	33.70	6.06
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 400 lbs. (nitrogen, 50 lbs.)							
1889	Plot 14, . . .	Spe. nitrogen	720	4.50	1.92	53.32	34.74	5.52
1889	14, . . .	"	748	3.69	1.97	53.49	34.89	5.96
	Average,			4.10	1.94	53.41	34.81	5.74
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 600 lbs. (nitrogen, 75 lbs.)							
1889	Plot 15, . . .	Spe. nitrogen	722	4.38	1.70	53.82	34.45	5.65
1889	15, . . .	"	750	4.56	2.10	52.05	35.41	5.88
	Average,			4.47	1.90	52.93	34.93	5.77

TABLE 29.—*Effects of nitrogenous fertilizers upon corn (grain, flint varieties).*

[The details of the experiments may be found in the Reports of the Station for the years in which the several experiments were made or for the year following.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	YIELDS OF DRY MATTER AND NUTRIENTS IN CORN PER ACRE.					
			Water free substance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1888	Plots o and oo, . .	Soil test	1,043	116	54	839	16	18
1888	o and oo, . .	Spe. nitrogen	914	119	52	716	13	14
1888	o and oo, . .	"	662	77	37	526	10	12
1888	o and oo, . .	"	1,045	126	56	830	17	17
1889	o and oo, . .	"	233	29	12	183	4	4
1889	o and oo, . .	"	549	63	33	430	12	11
1889	o and oo, . .	Soil test	234	26	12	187	5	4
1890	o and oo, . .	"	2,204	227	143	1,767	33	34
1890	o and oo, . .	"	259	30	13	206	5	5
1895	o, ...	Spe. nitrogen	1,646	175	92	1,327	25	28
1895	oo, ...	"	2,040	214	121	1,638	32	36
1896	o, ...	"	1,427	143	83	1,147	29	25
1896	oo, ...	"	1,579	177	84	1,267	24	28
	Average,		**1,064**	**118**	**61**	**851**	**17**	**18**
	Nitrate of soda, 160 lbs.							
1888	Plot A, ...	Soil test	1,596	175	82	1,290	24	25
1888	1, ...	Spe. nitrogen	992	131	53	777	15	16
1888	1, ...	"	1,267	147	76	1,001	21	22
1889	1, ...	"	325	41	17	254	7	6
1889	A, ...	Soil test	448	54	26	350	10	9
1890	A, ...	"	2,569	292	130	2,072	37	38
1890	A, ...	"	667	79	34	532	11	11
	Average,		**1,123**	**131**	**60**	**897**	**18**	**18**
	Dissolved Boneblack, 320 lbs.							
1888	Plot B, ...	Soil test	1,208	138	64	970	17	19
1888	2, ...	Spe. nitrogen	1,419	190	80	1,106	20	23
1888	2, ...	"	953	105	53	762	15	18
1889	2, ...	"	229	30	12	177	5	5
1889	2, ...	"	648	68	34	521	13	12
1889	B, ...	Soil test	442	49	23	353	9	8
1890	B, ...	"	2,006	208	104	1,633	29	32
1890	B, ...	"	239	26	11	194	4	4
	Average,		**893**	**102**	**48**	**715**	**14**	**15**
	Muriate of potash, 160 lbs.							
1888	Plot C, ...	Soil test	1,113	110	58	909	17	19
1888	3, ...	Spe. nitrogen	1,241	162	65	972	21	21
1888	3, ...	"	1,568	161	87	1,270	23	27
1889	3, ...	"	1,153	118	65	927	21	22
1889	3, ...	"	608	63	30	491	13	11
1889	C, ...	Soil test	360	40	19	287	7	7
1890	C, ...	"	2,347	243	120	1,916	33	35
1890	C, ...	"	355	30	18	295	7	5
	Average,		**1,093**	**116**	**58**	**883**	**18**	**18**

TABLE 29.— CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Yields of dry matter and nutrients in corn per acre. Water free substance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dissolved boneblack, 320 lbs. Nitrate of soda, 160 lbs.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1888	Plot D, . . .	Soil test	1,556	186	90	1,229	24	27
1888	4, . . .	Spe. nitrogen	1,617	216	103	1,246	24	28
1888	4, . . .	"	1,087	135	61	853	18	20
1889	4, . . .	"	467	58	32	361	7	9
1889	D, . . .	Soil test	517	59	26	412	10	10
1890	D, . . .	"	2,781	318	146	2,233	41	43
1890	D, . . .	"	845	96	43	677	15	14
	Average,		1,267	153	72	1,002	20	22
	Nitrate of soda, 160 lbs. Muriate of potash, 160 lbs.							
1888	Plot E, . . .	Soil test	1,836	238	100	1,439	28	31
1888	5, . . .	Spe. nitrogen	1,269	167	72	991	20	19
1888	5, . . .	"	1,776	207	100	1,409	29	31
1889	5, . . .	"	1,411	147	88	1,120	26	30
1889	E, . . .	Soil test	463	56	24	364	9	10
1890	E, . . .	"	2,797	285	141	2,288	39	44
1890	E, . . .	"	2,317	209	118	1,919	38	23
	Average,		1,696	187	92	1,361	27	27
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen, —							
1888	Plot F, . . .	Soil test	1,256	135	67	1,012	21	21
1888	6, 6*a* and 6*b*, .	Spe. nitrogen	1,884	236	105	1,486	29	29
1888	6, 6*a* and 6*b*, .	"	1,497	148	84	1,216	23	26
1888	6, 6*a*, 6*b*, 6*c*, .	"	1,308	149	73	1,043	21	22
1889	6, 6*a*, 6*b*, 6*c*, .	"	808	78	51	650	14	15
1889	6, 6*a*, . . .	"	773	84	52	603	17	17
1889	F, . . .	Soil test	306	34	15	246	5	6
1890	F, . . .	"	2,159	221	116	1,758	29	35
1890	F, . . .	"	456	38	24	379	8	7
1895	6*a*, . . .	Spe. nitrogen	2,502	221	155	2,032	51	43
1895	6*b*, . . .	"	2,825	286	185	2,259	43	52
1896	6*a*, . . .	"	2,148	201	130	1,735	44	38
1896	6*b*, . . .	"	2,613	253	140	2,143	33	44
	Average,		1,580	160	92	1,274	26	27
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen diff. forms, 25 lbs.							
1888	Plot G, . . .	Soil test	1,900	222	100	1,515	30	33
1888	7, 10, 13, . .	Spe. nitrogen	2,040	254	116	1,609	29	32
1889	7, 10, 13, . .	"	2,040	208	111	1,658	30	33
1888	7, 10, 13, . .	"	1,417	180	77	1,111	26	23
1889	7, 10, 13, . .	"	1,553	154	108	1,231	29	31
1889	7, 10, 13, . .	"	1,015	105	58	811	22	19
1889	G, . . .	Soil test	757	83	38	609	14	13
1890	G, . . .	"	2,818	320	150	2,264	39	44

TABLE 29.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Yields of dry matter and nutrients in corn per acre.					
			Water free substance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, etc.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1890	Plot G, . . .	Soil test	1,802	163	97	1,487	28	26
1895	7, . . .	Spe. nitrogen	3,311	340	210	2,655	49	57
1895	10, . . .	"	3,245	351	237	2,538	52	67
1896	7, . . .	"	3,150	306	195	2,548	47	54
1896	10, . . .	"	2,265	281	153	2,147	35	49
	Average,		**2,132**	**228**	**127**	**1,706**	**33**	**37**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen (diff. forms), 50 lbs.							
1888	Plots 8, 11, 14, . .	Spe. nitrogen	2,036	270	117	1,586	30	33
1888	8, 11, 14, . .	"	2,256	237	121	1,826	36	36
1888	8, 11, 14, . .	"	1,622	199	90	1,280	27	26
1889	8, 11, 14, . .	"	2,305	227	154	1,839	42	43
1889	8, 11, 14, . .	"	1,267	139	71	1,006	28	23
1895	8, . . .	"	3,565	380	224	2,847	53	61
1895	11, . . .	"	3,555	414	256	2,760	55	70
1896	8, . . .	"	3,434	354	220	2,747	51	62
1896	11, . . .	"	3,463	387	230	2,721	57	68
	Average,		**2,611**	**290**	**165**	**2,068**	**42**	**47**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen (diff. forms), 75 lbs.							
1888	Plots 9, 12, 15, . .	Spe. nitrogen	1,950	280	111	1,499	27	33
1888	9, 12, 15, . .	"	2,420	284	136	1,922	37	41
1888	9, 12, 15, . .	"	1,442	190	81	1,124	24	23
1889	9, 12, 15, . .	"	2,429	246	157	1,933	45	48
1889	9, 12, 15, . .	"	1,375	151	84	1,083	29	28
1895	9, . . .	"	3,585	431	227	2,807	56	64
1895	12, . . .	"	3,517	434	248	2,709	54	72
1896	9, . . .	"	3,808	434	237	3,017	52	68
1896	12, . . .	"	3,508	430	211	2,750	51	66
	Average,		**2,670**	**320**	**166**	**9,094**	**42**	**49**

TABLE 30.—*Effects of nitrogenous fertilizers upon corn stover (flint varieties).*

[The details of the experiments may be found in the Reports of the Station for the years in which the several experiments were made or for the year following.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Yields of dry matter and nutrients in corn stover per acre.					
			Water free sub-stance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1888	Plots o and oo, . .	Soil test	1,075	51	18	544	400	62
1888	o and oo, . .	Spe. nitrogen	958	96	25	463	298	76
1888	o and oo, . .	"	1,263	104	31	661	388	78
1888	o and oo, . .	"	1,556	111	25	751	558	111
1889	o and oo, . .	"	568	45	10	276	207	31
1889	o and oo, . .	"	1,120	72	23	581	380	64
1889	o and oo, . .	Soil test	549	40	12	288	180	31
1890	o and oo, . .	"	1,711	85	30	859	647	91
1890	o and oo, . .	"	762	72	13	397	242	37
1895	o, ...	Spe. nitrogen	2,254	132	37	1,172	808	104
1895	oo, ...	"	1,738	110	31	927	552	118
1896	o, ...	"	1,775	128	28	873	612	133
1896	oo, ...	"	1,102	75	19	543	383	82
	Average,		**1,264**	**86**	**23**	**641**	**435**	**78**
	Nitrate of soda, 160 lbs.							
1888	Plot A, ...	Soil test	1,415	80	30	711	519	75
1888	1, ...	Spe. nitrogen	1,006	98	24	494	320	70
1888	1, ...	"	1,819	128	32	961	596	102
1889	1, ...	"	653	63	11	356	194	29
1889	A, ...	Soil test	640	55	12	327	211	36
1890	A, ...	"	1,938	103	41	962	735	97
1890	A, ...	"	1,161	112	19	600	372	58
	Average,		**1,233**	**91**	**24**	**630**	**421**	**67**
	Dissolved boneblack, 320 lbs.							
1888	Plot B, ...	Soil test	1,434	64	26	735	526	83
1888	2, ...	Spe. nitrogen	1,273	120	29	610	410	104
1888	2, ...	"	1,483	103	33	777	472	98
1889	2, ...	"	568	53	10	300	175	30
1889	2, ...	"	1,613	76	33	855	562	87
1889	B, ...	Soil test	755	58	15	391	249	42
1890	B, ...	"	1,563	68	35	788	589	83
1890	B, ...	"	654	66	10	330	212	36
	Average,		**1,168**	**76**	**24**	**598**	**399**	**70**
	Muriate of potash, 160 lbs.							
1888	Plot C, ...	Soil test	1,207	52	25	615	444	71
1888	3, ...	Spe. nitrogen	1,039	106	23	514	324	72
1888	3, ...	"	1,749	125	38	885	568	133
1889	3, ...	"	1,329	75	26	757	398	73
1889	3, ...	"	1,206	54	22	671	393	66
1889	C, ...	Soil test	699	49	14	363	232	41
1890	C, ...	"	1,815	81	37	895	691	111
1890	C, ...	"	1,520	130	47	761	500	82
	Average,		**1,321**	**84**	**29**	**683**	**444**	**81**

TABLE 30. — CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	YIELDS OF DRY MATTER AND NUTRIENTS IN CORN STOVER PER ACRE. Water-free sub-stance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dissolved boneblack, 320 lbs. Nitrate of soda, 160 lbs.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1888	Plot D, . . .	Soil test	1,665	91	32	855	601	86
1888	4, . . .	Spe. nitrogen	1,345	119	28	671	441	86
1888	4, . . .	"	1,965	176	34	1,011	631	113
1889	4, . . .	"	774	72	13	415	234	40
1889	D, . . .	Soil test	762	60	16	391	251	44
1890	D, . . .	"	2,145	105	43	1,101	790	106
1890	D, . . .	"	1,261	114	19	640	428	60
	Average,		**1,417**	**105**	**26**	**726**	**482**	**76**
	Muriate of potash, 160 lbs. Nitrate of soda, 160 lbs.							
1888	Plot E, . . .	Soil test	1,720	95	31	853	637	104
1888	5, . . .	Spe. nitrogen	1,236	115	27	589	410	95
1888	5, . . .	"	1,726	133	37	881	567	108
1889	5, . . .	"	1,758	97	31	922	603	105
1889	E, . . .	Soil test	802	67	15	413	263	44
1890	E, . . .	"	1,856	89	38	922	698	109
1890	E, . . .	"	2,022	116	42	1,052	704	108
	Average,		**1,589**	**102**	**32**	**805**	**555**	**96**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen, —							
1888	Plot F, . . .	Soil test	1,459	64	26	746	533	90
1888	6, 6*a*, 6*b*, . .	Spe. nitrogen	1,522	134	31	725	509	123
1888	6, 6*a*, 6*b*, 6*c*, .	"	1,894	116	50	976	615	137
1888	6, 6*a*, 6*b*, 6*c*, .	"	1,517	107	24	737	535	114
1889	6, 6*a*, 6*b*, 6*c*, .	"	1,349	63	30	763	420	73
1889	6, 6*a*, . .	"	1,559	79	27	857	496	100
1889	F, . . .	Soil test	793	52	20	414	256	51
1890	F, . . .	"	2,038	82	39	1,027	766	124
1890	F, . . .	"	1,889	80	50	1,044	619	96
1895	6*a*, . . .	Spe. nitrogen	2,920	106	60	1,595	967	192
1895	6*b*, . . .	"	3,004	110	62	1,641	994	197
1896	6*a*, . . .	"	2,379	124	52	1,181	849	173
1896	6*b*, . . .	"	2,065	96	40	1,040	717	172
	Average,		**1,876**	**93**	**39**	**980**	**637**	**126**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen (diff. forms) 25 lbs.							
1888	Plot G, . . .	Soil test	1,897	91	30	971	689	116
1888	7, 10, 13, . .	Spe. nitrogen	1,341	108	29	659	444	101
1888	7, 10, 13, . .	"	2,152	133	44	1,107	707	161
1888	7, 10, 13, . .	"	1,619	133	30	756	577	123
1889	7, 10, 13, . .	"	1,618	78	29	886	538	87
1889	7, 10, 13, . .	"	1,791	89	32	952	610	108
1889	G, . . .	Soil test	996	87	20	494	336	59
1890	G, . . .	"	2,130	102	45	1,080	777	126
1890	G, . . .	Soil test	2,775	142	52	1,438	980	163
1895	7, . . .	Spe. nitrogen	3,001	167	53	1,583	1,043	155
1895	10, . . .	"	2,852	111	50	1,550	971	170

TABLE 30. — CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	YIELDS OF DRY MATTER AND NUTRIENTS IN CORN STOVER PER ACRE. Water free substance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dissolved boneblack, etc.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1896	7, ...	"	3,271	176	70	1,551	1,241	233
1896	10, ...	"	2,495	120	55	1,276	836	208
	Average,		**2,149**	**118**	**41**	**1,100**	**750**	**139**
	Dissolved boneblack, 320 lbs.							
	Muriate of potash, 160 lbs.							
	Nitrogen (diff. forms), 50 lbs.							
1888	Plots 8, 11, 14, . .	Spe. nitrogen	1,629	152	53	769	537	138
1888	8, 11, 14, . .	"	2,317	136	44	1,197	791	149
1888	8, 11, 14, . .	"	1,776	141	34	859	619	123
1889	8, 11, 14, . .	"	2,015	93	36	1,070	704	112
1889	8, 11, 14, . .	"	1,784	84	31	938	629	104
1895	8, ...	"	2,930	152	57	1,545	1,026	150
1895	11, ...	"	2,802	138	50	1,521	916	177
1896	8, ...	"	3,038	200	57	1,456	1,103	222
1896	11, ...	"	2,152	127	44	1,061	750	170
	Average,		**2,271**	**136**	**45**	**1,157**	**786**	**149**
	Dissolved boneblack, 320 lbs.							
	Muriate of potash, 160 lbs.							
	Nitrogen (diff. forms), 75 lbs.							
1888	Plots 9, 12, 15, . .	Spe. nitrogen	1,461	165	29	685	452	130
1888	9, 12, 15, . .	"	2,343	171	44	1,139	834	155
1888	9, 12, 15. . .	"	1,721	150	24	789	594	164
1889	9, 12, 15, . .	"	2,026	100	32	1,072	710	112
1889	9, 12, 15, . .	"	1,717	93	36	887	602	99
1895	9, ...	"	3,320	172	59	1,727	1,192	170
1895	12, ...	"	2,974	199	54	1,567	929	225
1896	9, ...	"	2,919	227	56	1,394	1,021	221
1896	12, ...	"	2,869	219	54	1,394	989	213
	Average.		**2,372**	**166**	**43**	**1,184**	**814**	**165**

Explanation of Tables 31, 32, 33, and 34. — Tables 31-32 show the individual analyses of samples of oats (grain) and oat straw from all the individual experiments with this crop. Samples of the crops from both soil tests and special nitrogen experiments are analyzed, and the results averaged as already explained, and the averages given in the summary Tables 15 and 16 on pages 142 and 144 in the discussion.

Tables 33 and 34 show the yields of water-free substance and of various food constituents per acre, estimated in the manner for the other crops. The averages in bold face type in these tables are the values used in the summary Table 17 on page 146, in the discussion of the results.

TABLE 31.—*Effects of nitrogenous fertilizers upon oats (grain.)*

[The details of the analyses may be found in the Reports of the Station for the years in which the several experiments were made or for the succeeding year.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of oats calculated on water-free substance.				
				Protien.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1890	Plot o, ...	Spe. nitrogen	837	14.25	5.48	62.52	14.33	3.42
1890	oo, ...	"	839	13.60	5.63	62.75	14.61	3.41
1890	ooo, ...	"	841	13.12	5.47	62.42	15.96	3.03
1892	o, ...	Soil test	1,073	15.75	5.88	64.41	10.35	3.61
1892	oo, ...	"	1,074	14.81	5.65	67.46	8.39	3.69
1892	ooo, ...	"	1,075	13.75	5.43	66.50	10.59	3.73
1892	o.	Spe nitrogen	1,085	16.31	6.21	66.32	8.02	3.14
1892	oo, ...	"	1,086	15.68	6.48	66.58	8.16	3.10
1896	o, ...	Soil test	1,715	13.17	6.34	68.81	8.51	3.17
1896	oo, ...	"	1,716	12.90	6.26	67.97	9.40	3.47
1896	ooo, ...	"	1,717	13.13	5.90	67.91	9.77	3.29
	Average,		......	**14.22**	**5.88**	**65.79**	**10.74**	**3.37**
	Nitrate of soda, 160 lbs.							
1892	Plot A, ...	Soil test	1,076	15.31	5.64	65.75	9.90	3.40
1896	A, ...	"	1,706	14.85	6.55	68.13	7.23	3.24
	Average,		......	**15.08**	**6.10**	**66.94**	**8.56**	**3.32**
	Dis. boneblack, 320 lbs.							
1892	Plot B, ...	Soil test	1,077	14.19	5.62	66.80	9.78	3.61
1896	B, ...	"	1,707	12.31	6.46	68.97	8.67	3.59
	Average,		......	**13.25**	**6.04**	**67.88**	**9.23**	**3.60**
	Muriate of potash, 160 lbs.							
1892	Plot C, ...	Soil test	1,078	14.75	5.76	67.01	9.05	3.43
1896	C, ...	"	1,708	12.67	6.27	68.58	9.12	3.36
	Average,		.....	**13.71**	**6.02**	**67.79**	**9.08**	**3.40**
	Dis. boneblack, 320 lbs. *Nitrate of soda, 160 lbs.*							
1892	Plot D, ...	Soil test	1,079	14.63	6.06	67.12	8.98	3.21
1896	D, ...	"	1,709	12.74	6.36	70.56	7.32	3.02
	Average,		......	**13.68**	**6.21**	**68.84**	**8.15**	**3.12**
	Muriate of potash, 160 lbs. *Nitrate of soda, 160 lbs.*							
1892	Plot E, ...	Soil test	1,080	14.81	5.77	66.24	9.82	3.36
1896	E, ...	"	1,710	14.12	6.52	68.77	7.61	2.98
	Average,		......	**14.46**	**6.15**	**67.50**	**8.72**	**3.17**
	Dis. boneblack, 320 lbs. *Muriate of potash, 160 lbs.* *Nitrogen, —.*							
1890	Plot 6*a*, ...	Spe. nitrogen	843	14.38	5.63	63.57	13.22	3.20
1890	6*b*, ...	"	845	14.25	5.93	65.19	11.81	2.82
1892	F, ...	Soil test	1,081	13.68	5.39	67.14	10.25	3.54
1892	6, ...	Spe. nitrogen	1,087	15.68	6.09	67.26	7.77	3.20

TABLE 31.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of oats calculated on water-free substance.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, etc.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1892	Plot 6*a*, . . .	Spe. nitrogen	1,088	14.69	6.30	67.28	8.52	3.21
1892	6*b*, . . .	"	1,089	16.19	6.59	68.17	6.13	2.92
1892	6*c*, . . .	"	1,090	17.19	6.42	66.59	6.75	3.05
1896	F, . . .	Soil test	1,711	12.02	6.45	71.03	7.48	3.02
	Average,		......	**14.76**	**6.10**	**67.03**	**8.99**	**3.12**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1890	Plot 7, . . .	Spe. nitrogen	847	15.70	6.22	65.10	10.13	2.85
1892	G, . . .	Soil test	1,082	14.56	5.78	68.34	8.22	3.10
1892	7, . . .	Spe. nitrogen	1,091	16.56	6.00	66.83	7.70	2.91
1896	G, . . .	Soil test	1,712	11.89	6.04	69.29	9.78	3.00
	Average,		......	**14.68**	**6.01**	**67.39**	**8.96**	**2.96**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitr. of soda, 320 lbs. (nitrogen, 50 lbs.)							
1890	Plot 8, . . .	Spe. nitrogen	849	16.31	6.03	64.52	10.49	2.65
1892	8, . . .	"	1,092	16.38	5.54	65.65	9.45	2.98
	Average,		......	**16.34**	**5.79**	**65.08**	**9.97**	**2.82**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)							
1890	Plot 9, . . .	Spe. nitrogen	851	16.75	6.14	63.72	10.74	2.65
1892	9, . . .	"	1,093	17.19	5.22	64.14	10.37	3.08
	Average,		......	**16.97**	**5.68**	**63.93**	**10.55**	**2.87**
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Sul. of ammo., 120 lbs. (nitrogen, 25 lbs.)							
1890	Plot 10, . . .	Spe. nitrogen	853	13.94	6.05	64.90	12.25	2.86
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Sul. of ammo., 240 lbs. (nitroogen, 50 lbs.)							
1890	Plot 11, . . .	Spe. nitrogen	855	15.12	6.14	64.45	11.59	2.70
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Sul. of ammo., 360 lbs. (nitrogen, 75 lbs.)							
1890	Plot 12, . . .	Spe. nitrogen	857	15.00	5.86	62.38	13.84	2.92

TABLE 31.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of oats calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 200 lbs. (nitrogen, 25 lbs.)			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1890	Plot 13, . . .	Spe. nitrogen	859	14.50	6.00	64.85	11.88	2.77
1892	13, . . .	"	1,094	15.50	5.68	66.73	8.90	3.19
	Average,		......	15.00	5.84	65.79	10.39	2.98
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood. 400 lbs. (nitrogen, 50 lbs.)							
1890	Plot 14, . . .	Spe. nitrogen	861	14.06	5.85	65.22	12.13	2.74
1892	14, . . .	"	1,095	15.88	5.77	66.33	8.97	3.05
	Average,		......	14.97	5.81	65.77	10.55	2.90
	Dis. boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 600 lbs. (nitrogen, 75 lbs.)							
1890	Plot 15, . . .	Spe. nitrogen	863	14.69	5.98	64.91	11.74	2.68
1892	15, . . .	"	1,096	17.06	5.91	66.50	7.59	2.94
	Average,		.....	15.87	5.95	65.70	9.67	2.81

TABLE 32.—*Effects of nitrogenous fertilizers upon oat straw.*

[The details of the analyses may be found in the Reports of the Station for the years in which the several experiments were made or for the succeeding year.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of oat straw calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1890	Plot, 0, . . .	Spe. nitrogen	836	8.63	3.90	48.21	34.49	4.77
1890	00, . . .	"	838	8.31	3.09	48.99	35.26	4.35
1890	000, . . .	"	840	9.00	3.44	48.67	34.71	4.18
1892	0, . . .	"	1,097	5.44	3.02	44.98	40.39	6.17
1892	00, . . .	"	1,098	5.56	3.37	46.16	39.35	5.56
	Average,		....	7.39	3.36	47.40	36.84	5.01
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen,—							
1890	Plot 6*a*, . . .	Spe. nitrogen	842	6.13	3.40	48.35	37.15	4.97
1890	6*b*, . . .	"	844	5.94	3.42	49.04	33.31	4.29
1892	6 . . .	"	1,099	4.81	3.01	44.50	41.36	6.32
1892	6*a*, . . .	"	1,100	4.81	2.87	46.02	40.45	5.85
1892	6*b*, . . .	"	1,101	3.69	2.90	45.68	41.54	6.19
1892	6*c*, . . .	"	1,102	4.88	2.69	44.89	41.88	5.66
	Average,		...	5.04	3.05	46.41	39.95	5.55
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrate of soda, 160 lbs. (nitrogen, 25 lbs.)							
1890	Plot 7, . . .	Spe. nitrogen	846	5.06	3.84	47.82	38.52	4.76
1892	7, . . .	"	1,103	4.19	2.49	45.07	42.78	5.47
	Average,		...	4.63	3.16	46.44	40.65	5.12
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrate of soda, 320 lbs. (nitrogen, 50 lbs.)							
1890	Plot 8, . . .	Spe. nitrogen	848	5.25	3.32	48.29	38.49	4.65
1892	8, . . .	"	1,104	4.56	2.57	44.66	42.70	5 51
	Average.		...	4.90	2.95	46.47	40.60	5.08
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrate of soda, 480 lbs. (nitrogen, 75 lbs.)							
1890	Plot 9, . . .	Spe. nitrogen	850	6.00	3.56	47.23	38.19	5.02
1892	9, . . .	"	1,105	6.06	2.37	43.55	42.28	5.74
	Average,		....	6.03	2.97	45.39	40.23	5.38
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Sulphate of ammonia, 120 lbs. (nitrogen, 25 lbs.)							
1890	Plot 10, . . .	Spe. nitrogen	852	5.69	3.60	49.56	36.61	4.54

TABLE 32.— CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of oat straw calculated on water-free substance.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Sulphate of ammonia, 240 lbs. (nitrogen, 50 lbs.)			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1890	Plot 11, . . .	Spe. nitrogen	854	6.81	3.38	48.66	37.00	4.15
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Sulphate of ammonia, 360 lbs. (nitrogen, 75 lbs.)							
1890	Plot 12, . . .	Spe. nitrogen	856	7.50	3.18	48.15	37.05	4.12
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 200 lbs. (nitrogen, 25 lbs.)							
1890	Plot 13, . . .	Spe. nitrogen	858	5.63	3.19	48.52	38.27	4.39
1892	13, . . .	"	1,106	3.88	2.82	44.52	43.24	5.54
	Average,		....	**4.75**	**3.01**	**46.52**	**40.75**	**4.97**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs Dried blood, 400 lbs. (nitrogen, 50 lbs.)							
1890	Plot 14, . . .	Spe. nitrogen	860	5.25	3.17	48.95	38.12	4.51
1892	14, . . .	"	1,107	4.38	2.73	45.32	41.91	5.66
	Average,		....	**4.82**	**2.95**	**47.13**	**40.02**	**5.08**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Dried blood, 600 lbs. (nitrogen, 75 lbs.)							
1890	Plot 15, . . .	Spe. nitrogen	862	5.38	3.19	48.86	38.12	4.45
1892	15, . . .	"	1,108	5.17	2.88	46.20	40.62	5.13
	Average,		....	**5.27**	**3.04**	**47.53**	**39.37**	**4.79**

TABLE 33.—*Effects of nitrogenous fertilizers upon oats (grain).*

[The details of the experiments may be found in the Reports of the Station for the years in which the several experiments were made or for the year following.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Yields of dry matter and nutrients in oats per acre.					
			Water free substance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1890	Plot 0, ...	Spe. nitrogen	102	15	6	62	15	4
1890	00, ...	"	49	7	3	30	7	2
1890	000, ...	"	87	11	5	54	14	3
1892	0, ...	"	600	97	37	399	48	19
1892	00, ...	"	449	70	29	299	37	14
1892	0, ...	Soil test	786	124	46	507	81	28
1892	00, ...	"	658	98	37	444	55	24
1892	000, ...	"	637	88	35	423	67	24
	Average,		**421**	**64**	**25**	**277**	**41**	**15**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen, —							
1890	Plot 6*a*, ...	Spe. nitrogen	254	37	14	161	34	8
1890	6*b*, ...	"	324	46	19	212	38	9
1892	6, ...	"	523	82	32	351	41	17
1892	6*a*, ...	"	417	61	26	281	36	13
1892	6*b*, ...	"	515	83	34	351	32	15
1892	6*c*, ...	"	547	94	35	364	37	17
	Average,		**430**	**67**	**27**	**287**	**36**	**13**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen (diff. forms), 25 lbs.							
1890	Plots 7, 10, 13, . .	Spe. nitrogen	366	55	23	237	41	10
1892	7, 13, . .	"	676	109	40	450	56	21
	Average,		**521**	**82**	**32**	**344**	**49**	**16**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen (diff. forms), 50 lbs.							
1890	Plots 8, 11, 14, . .	Spe. nitrogen	428	66	26	276	49	11
1892	8, 14, . .	"	697	113	40	458	65	21
	Average,		**563**	**90**	**33**	**367**	**57**	**16**
	Dissolved boneblack, 320 lbs. Muriate of potash, 160 lbs. Nitrogen (diff. forms) 75 lbs.							
1890	Plots 9, 12, 15, . .	Spe. nitrogen	528	82	32	337	63	14
1892	9, 15, . ,	"	724	124	40	472	66	22
	Average,		**626**	**103**	**36**	**405**	**65**	**18**

TABLE 34.—*Effects of nitrogenous fertilizers upon oat straw.*

[The details of the experiments may be found in the Reports of the Station for the years in which the several experiments were made or for the year following.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	YIELD OF DRY MATTER AND NUTRIENTS IN OAT STRAW PER ACRE.					
			Water free substance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1890	Plot 0, ...	Spe. nitrogen	165	14	6	80	57	8
1890	00, ...	"	114	10	4	55	40	5
1890	000, . . .	"	222	20	8	108	77	9
1892	0, ...	"	1,292	70	39	581	522	80
1892	00, ...	"	933	52	32	430	367	52
	Average,		545	33	18	251	213	31
	Dissolved boneblack, 320 lbs. *Muriate of potash, 160 lbs.* *Nitrogen,—*							
1890	Plot 6*a*, ...	Spe. nitrogen	448	28	15	217	166	22
1890	6*b*, ...	"	491	29	17	241	183	21
1892	6, ...	"	987	47	30	440	408	62
1892	6*a*, ...	"	1,312	63	38	603	531	77
1892	6*b*, ...	"	1,241	46	36	566	516	77
1892	6*c*, ...	"	1,034	50	28	464	434	58
	Average,		919	44	27	422	373	53
	Dissolved boneblack, 320 lbs. *Muriate of potash, 160 lbs.* *Nitrogen (different forms), 25 lbs.*							
1890	Plots 7, 10, 13, . .	Spe. nitrogen	770	42	28	374	291	35
1892	7, 13, . .	"	1,757	72	47	786	755	97
	Average,		1,264	57	38	580	523	66
	Dissolved boneblack, 320 lbs. *Muriate of potash, 160 lbs.* *Nitrogen (different forms), 50 lbs.*							
1890	Plots 8, 11, 14, . .	Spe. nitrogen	911	52	30	442	346	41
1892	8, 14, . .	"	2,010	90	53	904	850	113
	Average,		1,461	71	42	673	598	77
	Dissolved boneblack, 320 lbs. *Muriate of potash, 160 lbs.* *Nitrogen (different forms), 75 lbs.*							
1890	Plots 9, 12, 15, . .	Spe. nitrogen	1,235	77	41	594	467	56
1892	9, 15, . .	"	2,567	146	67	1,146	1,067	141
	Average, .		1,901	112	54	870	767	99

Explanation of Table 35. — This table shows the results of the individual analyses of samples of different species of grasses grown on plots which received different quantities of nitrogen. These grasses were grown on small plots, mostly one-eightieth of an acre in size, in the Station grass garden. Owing to the small size of the plots no effort was made to determine the weight of the yield per acre. The general plan of the experiments was that of special nitrogen experiments, but with fewer plots. In most cases there were four plots for each kind of grass, and the experiments were continued on the same plots for three to seven years. The plots included in each experiment were generally a "nothing" plot, a "mineral" plot, a plot with the one-third ration, and a plot with the full ration of nitrogen, in addition to the minerals. In a few cases samples were taken from still smaller plots which were divided into two parts, one of which was supplied with the one-third and the other with the full ration of nitrogen.

The samples were usually taken at the time the grasses were in blossom, or soon after, and care was exercised to exclude from the sample of any particular grass any of the other species of grass or any clover that might be growing on the plot. The averages given in this table in bold face type appear in the summary Table 11, on page 134, in the discussion.

TABLE 35.—*Effect of nitrogenous fertilizers upon different species of grasses.*

[The details of the analyses may be found in the Reports of the Station for the years in which the several experiments were made or for the succeeding year.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Condition of growth when harvested.	Laboratory No.	Percentage composition of different species of grasses calculated on water-free substance.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	TIMOTHY. (PHLEUM PRATENSE.) *Nothing.*			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1891	Plot 0,	Early bloom	1,005	9.19	2.93	49.09	31.32	7 47
1892	0.	Seed forming	1,060	6.75	3.40	49.87	33.84	6.14
1893	0,	Early bloom	1,230	7.92	3.28	48.31	34.44	6.05
1894	0,	Late bloom	1,355	7.25	3.18	47.77	36.19	5.61
1896	0,	Seed forming	1,649	8.51	4.46	51.42	29.22	6.39
1897	0,	Seed forming	1,848	5.93	2.78	48.81	37.51	4.97
1898	0,	Full bloom	1,971	7.58	3.14	49.94	34.15	5.19
	Average,		......	7.59	3.31	49.32	33.81	5.97
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen, —							
1891	Plot 6,	Early bloom	1,004	9.06	2.94	48.46	31.78	7.76
1892	6,	Seed forming	1,061	6.25	2.97	49.17	35.18	6.43
1893	6,	Early bloom	1,231	7.72	2.80	47.95	35.06	6.47
1894	6,	Late bloom	1,356	6.79	2.67	52.55	31.69	6.30
1896	6,	Seed forming	1,654	6.41	3.32	51.68	32.68	5.91
1897	6,	Seed forming	1,847	6.26	3.03	52.12	32.77	5.82
1898	6,	Full bloom	1,972	6.72	2.82	49.08	35.29	6.09
	Average,		......	7.03	2.94	50.14	33.49	6.40
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (*nitrogen, 25 lbs.*)							
1891	Plot 7,	Early bloom	1,006	9.12	3.78	46.90	32.96	7.24
1892	7,	Seed forming	1,062	7.06	2.98	49.43	34.41	6.12
1893	7,	Early bloom	1,232	8.99	2.77	46.27	35.78	6.19
1894	7,	Late bloom	1,357	6.14	3.18	47.03	37.94	5.71
1896	7,	Seed forming	1,659	6.82	2.95	50.82	33.71	5.70
1897	7,	Seed forming	1,849	5.64	2.81	49.82	36.46	5.27
1898	7,	Full bloom	1,972	7.50	2.79	44.90	38.98	5.83
	Average,		......	7.32	3.04	47.88	35.75	6.01
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 480 lbs. (*nitrogen, 75 lbs.*)							
1891	Plot 9,	Early bloom	1,007	10.44	3.62	48.07	31.12	6.75
1892	9,	Seed forming	1,063	10.69	3.19	46.95	32.84	6.33
1893	9,	Early bloom	1,233	11.93	2.98	44.58	34.39	6.12
1894	9,	Late bloom	1,358	7.82	3.60	45.67	37.42	5.49
1896	9,	Seed forming	1,664	7.89	3.13	51.91	32.12	4.95
1897	9,	Seed forming	1,850	7.26	2.97	46.52	37.00	6.25
1898	9,	Full bloom	1,974	9.08	3.31	48.25	34.04	5.32
	Average,		......	9.30	3.26	47.42	34.13	5.89

TABLE 35.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Condition of growth when harvested.	Laboratory No.	Percentage composition of different species of grasses calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	ORCHARD GRASS. (DACTYLIS GLOMERATA.)							
	Nothing.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1891	Plot 0, . . .	Seed forming	1,001	8.37	5.42	44.90	32.37	8.94
1892	0, . . .	Seed forming	1,044	8.44	4.16	45.49	32.87	9 04
1893	0, . . .	Late bloom	1,226	8.30	3.56	44.71	36.38	7.05
1894	0, . . .	Seed forming	1,357	7.54	3.04	44.63	36.98	7.81
1896	0, . . .	Seed forming	1,650	10.09	5.25	43.65	31.47	9.54
1897	0. . . .	Late bloom	1,852	7.90	2.99	46.98	33.87	8.26
1898	0, . . .	Late bloom	1,963	6.25	3.41	48.29	35.32	6.73
	Average,		......	8.13	3.98	45.52	34.18	8.19
	Dis. boneblack, 310 lbs. Mur. of potash, 160 lbs. Nitrogen, —							
1891	Plot 6, . . .	Seed forming	1,000	9.56	4.66	45.20	30.92	9.66
1892	6, . . .	Seed forming	1,045	8.19	4.05	44.86	33.57	9.33
1893	6, . . .	Late bloom	1,227	7.73	3.45	45.01	36.13	7.68
1894	6, . . .	Seed forming	1,360	7.17	2.83	43.21	38.14	8.65
1896	6, . . .	Seed forming	1,655	9.53	5.03	42.67	32.40	10.37
1897	6, . . .	Late bloom	1,851	6.83	2.90	44.32	37.31	8.64
1898	6, . . .	Late bloom	1,964	6.38	3.12	46.62	35.96	7.92
	Average,		.....	7.91	3.72	44.56	34.92	8.89
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1891	Plot 7, . . .	Seed forming	1,002	8.75	4.55	44.30	32.83	9.57
1892	7, . . .	Seed forming	1,046	11.50	5.47	41.80	31.55	9.68
1893	7, . . .	Late bloom	1,228	11.97	3.86	42.08	33.42	8.67
1894	7, . . .	Seed forming	1,361	7.91	3.55	43.67	36.27	8.60
1896	7, . . .	Seed forming	1,660	10.07	4.62	39.85	35.43	10.03
1897	7, . . .	Late bloom	1,853	8.78	2.80	45.74	33.83	8.85
1898	7, . . .	Late bloom	1,965	8.17	3.60	45.46	33.55	9.22
	Average,		......	9.60	4.06	43.27	33.84	9.23
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)							
1891	Plot 9, . . .	Seed forming	1,003	9.62	4.93	44.96	30.82	9.67
1892	9, . . .	Seed forming	1,047	15.50	5.45	38.30	31.61	9.14
1893	9, . . .	Late bloom	1,229	16.80	4.45	38.64	31.23	8.88
1894	9, . . .	Seed forming	1,362	10.61	3.45	41.61	36.24	8.09
1896	9, . . .	Seed forming	1,665	11.83	5.38	42.55	31.67	8.57
1897	9, . . .	Late bloom	1,854	13.01	3.89	39.80	34.41	8.89
1898	9, . . .	Late bloom	1,966	11.05	4.08	43.44	32.84	8.59
	Average,		......	12.63	4.52	41.33	32.69	8.83

TABLE 35.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Condition of growth when harvested.	Laboratory No.	Percentage composition of different species of grasses calculated on water-free substance.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	TALL MEADOW FESCUE GRASS. (FESTUCA ELATIOR.) *Nothing.*			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1893	Plot 0, ...	Full bloom	1,222	7.47	2.63	46.32	36.48	7.10
1894	0, ...	Seed forming	1,351	5.94	2.44	40.19	44.40	7.03
1896	0, ...	Seed forming	1,651	9.36	4.85	48.59	28.79	8.41
1897	0, ...	Late bloom	1,856	6.30	2.57	44.17	40.24	6.72
1898	0, ...	Late bloom	1,975	6.75	2.54	52.77	31.61	6.33
	Average,		......	**7.16**	**3.01**	**46.41**	**36.30**	**7.12**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen, —							
1893	Plot 6, ...	Full bloom	1,223	7.76	2.85	46.04	36.04	7.31
1894	6, ...	Seed forming	1,352	5.98	2.39	50.25	34.13	7.25
1896	6, ...	Seed forming	1,656	9.24	3.86	50.10	28.97	7.83
1897	6, ...	Late bloom	1,855	5.99	2.52	48.03	35.74	7.72
1898	6, ...	Late bloom	1,976	6.85	2.69	49.28	33.57	7.61
	Average,		......	**7.16**	**2.86**	**48.74**	**33.69**	**7.55**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1891	Plot 7, ...	Seed forming	1,011	7.50	3.01	51.84	31.31	6.34
1893	7, ...	Full bloom	1,224	10.44	2.66	43.13	36.06	7.71
1894	7, ...	Seed forming	1,353	6.89	2.72	45.89	37.13	7.37
1896	7, ...	Seed forming	1,661	10.07	3.90	49.29	28.20	8.54
1897	7, ...	Late bloom	1,857	7.85	2.89	46.69	35.40	7.17
1898	7, ...	Late bloom	1,977	7.03	3.01	50.30	32.58	7.08
	Average,		......	**8.30**	**3.03**	**47.85**	**33.45**	**7.37**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)							
1891	Plot 9, ...	Seed forming	1,010	10.94	2.89	50.65	28.67	6.85
1893	9, ...	Full bloom	1,225	14.11	3.25	41.02	33.29	8.33
1894	9, ...	Seed forming	1,354	9.60	3.13	39.65	39.07	8.55
1896	9, ...	Seed forming	1,666	12.59	4.94	44.17	30.29	8.01
1897	9, ...	Late bloom	1,858	11.89	3.69	42.97	33.59	7.86
1898	9, ...	Late bloom	1,978	11.78	4.14	45.30	30.28	8.50
	Average,		......	**11.82**	**3.67**	**43.96**	**32.53**	**8 02**
	TALL RED TOP. (AGROSTIS VULGARIS MAJOR.) *Nothing.*							
1896	Plot 0, ...	Seed forming	1,653	6.70	3.23	53.19	29.60	7.28
1897	0, ...	Seed forming	1,860	7.08	3.21	51.79	31.32	6.60
	Average,			**6.89**	**3.22**	**52.49**	**30.46**	**6.94**

TABLE 35.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Condition of growth when harvested.	Laboratory No.	Percentage composition of different species of grasses calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen, —			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1896	Plot 6, . . .	Seed forming	1,658	6.62	3.30	53.32	30.34	6.42
1897	6, . . .	Seed forming	1,859	6.58	3.29	50.97	31.78	7.38
	Average,		......	**6.60**	**3.30**	**52.14**	**31.06**	**6.90**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1891	Plot 7, . . .	Full bloom	1,021	8.81	3.03	51.47	28.76	7.93
1892	7, . . .	Full bloom	1,064	7.56	2.79	49.73	32.75	7.17
1896	7, . . .	Seed forming	1,663	8.20	3.74	52.42	28.76	6.88
1897	7, . . .	Seed forming	1,861	6.33	3.04	54.95	29.99	5.69
	Average,		......	**7.73**	**3.15**	**52.14**	**30.06**	**6.92**
	Dis. boneblack, 320 lbs. Mur. of potash. 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)							
1891	Plot 9, . . .	Full bloom	1,027	13.31	3.36	48.16	26.87	8.30
1892	9, . . .	Full bloom	1,065	9.31	3.16	48.87	31.88	6.78
1896	9, . . .	Seed forming	1,668	9.86	3.50	52.11	28.39	6.14
1897	9, . . .	Seed forming	1,862	9.13	2.92	52.23	30.19	5.53
	Average,		......	**10.40**	**3.24**	**50.34**	**29.33**	**6.69**
	BROME GRASS. (BROMUS INERMIS.)							
	Nothing.							
1896	Plot 0, . . .	Seed forming	1,652	8.02	3.48	52.06	28.84	7.60
1898	0, . . .	Late bloom	1,967	8.24	3.24	49.05	31.94	7.53
	Average,		......	**8.13**	**3.36**	**50.55**	**30.39**	**7.57**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen, —							
1896	Plot 6, . . .	Seed forming	1,657	8.09	3.38	51.70	27.83	9.00
1898	6, . . .	Late bloom	1,968	8.24	3.31	49.35	30.86	8.24
	Average,		......	**8.17**	**3.35**	**50.52**	**29.34**	**8.62**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1896	Plot 7, . . .	Seed forming	1,662	9.39	3.51	50.82	28.52	7.76
1898	7, . . .	Late bloom	1,969	8.05	3.27	49.51	31.94	7.23
	Average,			**8.72**	**3.39**	**50.16**	**30.23**	**7.50**

TABLE 35.—CONTINUED.

Year.	Plot No and kind and amount of fertilizer per acre.	Condition of growth when harvested.	Laboratory No.	Percentage composition of different species of grasses calculated on water-free substance.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1896	Plot 9, ...	Seed forming	1,667	13.38	4.25	44.71	30.33	7.33
1898	9, ...	Late bloom	1,970	12.56	3 87	43.16	32.74	7.67
	Average,		......	12.97	4.06	43.93	31.54	7.50
	TALL MEADOW OAT GRASS. (AVENÆ ELATIOR.)							
	Nothing.							
1893	Plot 0, ...	Seed forming	1,218	7.68	3.13	47.11	35.02	7.06
1894	0, ...	Seed forming	1,347	7.98	3.02	45.04	36.71	7.25
	Average,		.....	7.83	3.08	46.07	35.87	7.15
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen,—							
1893	Plot 6, ...	Seed forming	1,219	7.42	3.12	45.90	36.17	7.39
1894	6, ...	Seed forming	1,348	7.57	3.17	44.08	37.44	7.74
	Average,		......	7.50	3 14	44.99	36.80	7.57
	Dis. boneblock, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1892	Plot 7, ...	Seed forming	1,048	10.50	3.06	44.88	34.07	7.49
1893	7, ...	Seed forming	1,220	10.72	3.53	44.23	34.45	7.07
1894	7, ...	Seed forming	1,349	8.68	3.19	45.55	35.91	6.67
	Average,		......	9.97	3.26	44.88	34.81	7.08
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)							
1892	Plot 9, ...	Seed forming	1,049	11.94	3.31	43.97	33.28	7.50
1893	9, ...	Seed forming	1,221	13.74	3.64	42.80	32.46	7.36
1894	9, ...	Seed forming	1,350	11.52	3.39	42.56	35.70	6 83
	Average,		......	12.40	3.45	43.11	33.81	7.23
	FOWL MEADOW GRASS. (POA SEROTINA.)							
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1891	Plot 7, ...	Full bloom	1,012	12.06	3.28	42.30	32.84	9.52

TABLE 35.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Condition of growth when harvested.	Laboratory No.	Percentage composition of different species of grasses calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
				Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1891	*Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda. 480 lbs. (nitrogen, 75 lbs.)* Plot 9, . . .	Full bloom	1,013	14.87	2.83	42.25	31.65	8.40
	KENTUCKY BLUE GRASS. (POA PRATENSIS.)							
1892	*Dis. boneblack. 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)* Plot 7, . . .	Seed forming	1,050	12.88	4.04	44.89	31.49	6.70
1892	*Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)* Plot 9, . . .	Seed forming	1,051	15.44	4.51	43.49	29.62	6.94
	ENGLISH RYE GRASS. (LOLIUM PERENNE.)							
1891	*Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)* Plot 7, . . .	Late bloom	1,008	12.62	2.92	48.69	27.71	8.06
1891	*Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)* Plot 9, . . .	Late bloom	1,009	10.87	2.71	50.79	27.54	8.09

Explanation of tables 36 and 37. — Table 36 gives the composition of samples of cow pea fodder grown in the special nitrogen experiments. These experiments include two plots with no fertilizer, two plots with mineral fertilizer only (phosphoric acid and potash), three plots with nitrate of soda and mineral fertilizer, and three plots with sulphate of ammonia and minerals. A few analyses of samples from a single soil test experiment were added, two from nothing plots, one from a mineral plot (F), and one from a plot (G) with the first nitrogen ration (25 pounds per acre). The cow peas were grown for green feed, or for silage, and the crop was harvested before many pods had formed — if any were present they were sampled with the fodder. The kinds and amounts of fertilizing materials and the quantities of nitrogen used on different plots are shown in the second column, and the kind of experiment in the third; the balance of the table shows the percentages of the various food constituents on the basis of water-free substance. The average composition of the crops from the different plots is shown in bold-faced type, which figures are used in the summary Table 20 on page 150 of the text of this article.

Table 37 gives the yield per acre of the water-free substance and of the various food constituents from different plots. The yields of water-free substance were calculated from the weight of the crop, and the percentages of water-free substance in the crop at the time of harvesting. The yields of protein, fat, etc., were obtained by multiplying the weights of water-free substance per acre in Table 37 by the percentages of protein, fat, etc., for the same plots in Table 36. The average yields given in bold face type in Table 37 are used in the summary Table 22, on page 153 of the text.

TABLE 36.—*Effects of nitrogenous fertilizers upon cow pea fodder.*

[The details of the analyses may be found in the Reports of the Station for the years in which the several experiments were made or for the succeeding year.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of cow pea fodder calculated on water-free substance.				
				Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1893	Plot o,	Soil test	1,234	17.11	3.76	47.50	19.95	11.68
1893	oo,	"	1,235	19.21	3.69	44.03	20.06	13.01
1893	ooo,	"	1,236	18.83	3.07	44.17	21.02	12.91
1893	o,	"	1,246	21.73	4.17	38.50	21.92	13.68
1895	o,	Spe. nitrogen	1,485	17.84	3.82	48.18	20.43	9.73
1895	oo,	"	1,486	15.05	3.77	49.62	22.15	9.41
1896	o,	"	1,718	16.82	2.92	42.99	25.23	12.04
1896	oo,	"	1,719	20.03	3.91	44.95	18.96	12.15
1897	o,	"	1,872	21.69	4.14	37.37	23.35	13.45
1897	oo,	"	1,880	18.13	3.03	44.02	23.46	11.36
1898	o,	"	6,002	16.26	3.17	48.52	22.99	9.06
1898	oo,	"	6,003	17.87	3.40	46.18	21.64	10.91
	Average,		......	**18.38**	**3.57**	**44.67**	**21.76**	**11.62**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen,—							
1893	Plot F,	Soil test	1,242	19.88	3.61	41.06	22.53	12.92
1894	6,	Spe. nitrogen	1,366	18.81	3.84	41.09	23.38	12.88
1895	6*a*,	"	1,487	16.73	3.47	45.31	24.87	9.62
1895	6*b*,	"	1,488	15.40	3.27	50.85	21.37	9.11
1896	6*a*,	"	1,720	19.66	3.59	41.40	22.55	12.80
1896	6*b*,	"	1,721	18.23	2.87	44.84	22.48	11.58
1897	6*a*,	"	1,871	19.25	3.12	44.77	22.24	10.62
1897	6*b*,	"	1,876	18.17	2.49	43.33	25.37	10.64
1898	6*a*,	"	6,004	17.98	2.91	45.50	24.50	9.11
1898	6*b*,	"	6,005	19.57	2.66	41.97	25.45	10.35
	Average,		......	**18.37**	**3.18**	**44.01**	**23.48**	**10.96**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 160 lbs. (nitrogen, 25 lbs.)							
1893	Plot G,	Soil test	1,243	18.02	3.58	42.65	22.24	13.51
1893	7,	Spe. nitrogen	1,247	21.06	4.11	37.88	23.06	13.89
1894	7,	"	1,367	17.81	4.28	44.49	29.85	12.47
1895	7,	"	1,489	17.57	3.21	46.54	23.69	8.99
1896	7,	"	1,722	16.81	2.98	46.15	22.97	11.09
1897	7,	"	1,879	17.68	2.86	43.82	25.38	10.26
1898	7,	"	6,006	16.38	2.85	48.35	24.49	7.93
	Average,		......	**17.90**	**3.41**	**44.27**	**23.25**	**11.17**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 320 lbs. (nitrogen, 50 lbs.)							
1895	Plot 8,	Spe. nitrogen	1,490	17.94	3.53	44.85	24.95	8.73
1896	8,	"	1,723	18.90	2.88	43.44	22.67	12.11
1897	8,	"	1,878	19.03	2.64	45.33	22.87	10.13
1898	8,	"	6,007	16.91	3.41	45.66	25.94	8.08
	Average,		......	**18.20**	**3.11**	**44.82**	**24.11**	**9.76**

TABLE 36.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of cow pea fodder calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitr. of soda, 480 lbs. (nitrogen, 75 lbs.)			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1893	Plot 9, . . .	Spe. nitrogen	1,248	20.02	4.63	40.44	23.06	11.85
1894	9, . . .	"	1,368	20.05	4.04	42.88	20.28	12.75
1895	9, . . .	"	1,491	18.28	3.81	47.38	21.39	9.14
1896	9. . . .	"	1,731	19.49	3.76	44.72	20.41	11.62
1897	9, . . .	"	1,877	18.43	2.55	43.72	24.95	10.35
1898	9, . . .	"	6,008	17.51	3.53	48.15	22.57	8.24
	Average,		......	18.96	3.72	44.55	22.11	10.66
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Sul. of Amm., 120 lbs. (nitrogen, 25 lbs.)							
1895	Plot 10, . . .	Spe. nitrogen	1,492	18.39	3.74	46.63	21.05	10.19
1896	10, . . .	"	1,724	19.02	3.07	41.67	24.39	11.85
1897	10, . . .	"	1,875	18.43	2.99	43.13	23.94	11.51
1898	10, . . .	"	6,009	16.82	3.16	45.26	25.15	9.61
	Average,		......	18.17	3.24	44.17	23.63	10.79
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Sul. of Amm., 240 lbs. (nitrogen, 50 lbs.)							
1895	Plot 11, . . .	Spe. nitrogen	1,493	18.20	4.21	46.78	20.17	10.64
1896	11, . . .	"	1,725	16.61	2.71	46.10	23.70	10.88
1897	11, . . .	"	1,874	15.91	3.63	47.08	22.49	10.89
1898	11, . . .	"	6,010	17.99	2.60	44.10	25.25	10.06
	Average,		......	17.18	3.29	46.01	22.90	10.62
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Sul. of Amm., 360 lbs. (nitrogen, 75 lbs.)							
1895	Plot 12, . . .	Spe. nitrogen	1,494	16.09	3.43	49.58	20.88	10.02
1896	12, . . .	"	1,726	21.39	2.63	38.43	24.25	13.30
1897	12, . . .	"	1,873	22.79	3.37	39.35	23.34	11.15
1898	12, . . .	"	6,011	17.03	2.77	46.54	23.39	10.27
	Average,		......	19.32	3.05	43.48	22.96	11.19

TABLE 37.—*Effects of nitrogenous fertilizers upon cow pea fodder.*

[The details of the experiments may be found in the Reports of the Station for the years in which the several experiments were made or for the year following.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	YIELD OF DRY MATTER AND NUTRIENTS IN COW PEA FODDER PER ACRE. Water free substance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1895	Plots 0, 00,	Spe. nitrogen	2,115	348	80	1,035	450	202
1896	0, 00,	"	2,111	390	72	927	467	255
1897	0, 00,	"	1,519	302	54	618	356	189
1898	0, 00,	"	1,985	339	65	940	443	198
	Average,		**1,932**	**344**	**68**	**880**	**429**	**211**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen.—							
1895	Plots 6*a*, 6*b*,	Spe. nitrogen	4,299	691	145	2,066	994	403
1896	6*a*, 6*b*,	"	3,510	665	113	1,515	790	427
1897	6*a*, 6*b*,	"	3,236	605	91	1,425	771	341
1898	6*a*, 6*b*,	"	3,743	703	104	1,637	935	364
	Average,		**3,697**	**666**	**113**	**1,661**	**873**	**384**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen (diff. forms), 25 lbs.							
1895	Plots 7, 10,	Spe. nitrogen	4,108	739	143	1,913	919	394
1896	7, 10,	"	3,861	645	110	1,781	901	424
1897	7, 10,	"	3,249	583	95	1,413	804	354
1898	7, 10,	"	4,195	696	126	1,964	1,041	368
	Average,		**3,853**	**666**	**118**	**1,768**	**916**	**385**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen (diff. forms), 50 lbs.							
1895	Plots 8, 11,	Spe. nitrogen	3,949	714	153	1,808	891	383
1896	8, 11,	"	3,753	756	104	1,536	880	477
1897	8, 11,	"	3,146	548	98	1,454	715	331
1898	8, 11,	"	3,923	684	118	1,760	1,004	356
	Average,		**3,693**	**665**	**118**	**1,640**	**873**	**387**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen (diff. forms), 75 lbs.							
1895	Plots 9, 12,	Spe. nitrogen	4,016	690	145	1,947	849	385
1896	9, 12,	"	3,547	683	121	1,532	795	416
1897	9, 12,	"	2,812	578	83	1,168	681	302
1898	9, 12,	"	4,107	709	129	1,945	944	380
	Average,		**3,620**	**665**	**119**	**1,648**	**817**	**371**

Explanation of Tables 38 and 39. — Table 38 gives analyses of samples of soy bean seeds from a series of special nitrogen experiments similar to those carried on with cow pea fodder. These experiments include two plots without fertilizer, two plots with mineral fertilizer (phosphoric acid and potash) only, three plots with nitrate of soda and mineral fertilizers, and three plots with sulphate of ammonia and mineral fertilizers. The analyses include only samples of the seed, as the vines dropped their leaves almost entirely before the seed was fully ripe, making it impracticable to sample the straw. The table shows the kinds and amounts of fertilizing materials and the quantities of nitrogen used, the kind of experiment, and the percentages of the various food constituents on the basis of water-free substance. The average composition of the crops from plots having the same kinds and amounts of fertilizers is shown in bold face type, which figures are used in the summary Table 21 on page 150 of the text.

Table 39 gives the yields per acre of water-free substance, and of the various food constituents. The yields of water-free substance were calculated from the total weights of the seed when the crop was threshed, and the proportion of water-free material found in the samples of the seeds at that time. The yields of food constituents were obtained by multiplying the weights of the water-free substance as shown in Table 39 by the percentages of the various food constituents as shown in Table 38. The average yields per acre of crops grown under similar conditions are given here in Table 39 in bold face, which figures are used in the summary Table 23 on page 153 in the text of the article.

TABLE 38.—*Effects of nitrogenous fertilizers upon soy beans (seeds).*

[The details of the analyses may be found in the Reports of the Station for the years in which the several experiments were made or for the succeeding year.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of soy beans calculated on water-free substance. Protein	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.			Per ct.	Per ct.	Per ct.	Per ct	Per ct.
1895	Plot o, ...	Spe. nitrogen	1,577	35.17	19.81	28.18	3.23	13.61
1895	oo, ...	"	1,578	39.31	20.17	27.90	3.27	9.35
1897	o, ...	"	1,836	38.14	18.16	30.07	8.75	4.88
1897	oo, ...	"	1,837	37.27	16.81	37.20	4.14	4.58
1898	o, ...	"	6,012	44.21	19.21	27.15	4.00	5.43
1898	oo, ...	"	6,013	45.65	19.86	25.43	3.62	5.44
	Average,			**39.96**	**19.00**	**29.32**	**4.50**	**7.22**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen, —							
1894	Plot 6, ...	Spe. nitrogen	1,363	40.20	18.10	30.62	4.98	6.10
1895	6*a*, ...	"	1,579	35.10	22.37	31.96	3.37	7.20
1895	6*b*, ...	"	1,580	38.05	21.34	30.57	3.52	6.52
1897	6*a*, ...	"	1,838	38.32	17.88	34.07	4.38	5.35
1897	6*b*, ...	"	1,839	38.55	17.66	33.86	4.52	5.41
1898	6*a*, ...	"	6,014	42.23	21.16	27.46	3.42	5.73
1898	6*b*, ...	"	6,015	42.64	21.54	26.88	3.25	5.69
	Average,			**39.30**	**20.01**	**30.77**	**3.92**	**6.00**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrate of soda, 160 lbs. (nitrogen, 25 lbs.)							
1894	Plot 7, ...	Spe. nitrogen	1,364	40.05	18.07	30.99	5.41	5.48
1895	7, ...	"	1,581	36.95	21.71	30.53	3.25	7.56
1897	7, ...	"	1,840	37.58	18.13	34.33	4.64	5.32
1898	7, ...	"	6,016	44.91	21.10	25.87	2.45	5.67
	Average,			**39.87**	**19.75**	**30.43**	**3.94**	**6.01**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrate of soda, 320 lbs. (nitrogen, 50 lbs.)							
1895	Plot 8, ...	Spe. nitrogen	1,582	39.29	21.44	29.90	3.26	6.11
1897	8, ...	"	1,841	38.00	18.25	31.07	6.80	5.88
1898	8, ...	"	6,017	44.77	20.31	26.88	2.55	5.49
	Average,			**40.69**	**20.00**	**29.28**	**4.20**	**5.83**
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrate of soda, 480 lbs. (nitrogen, 75 lbs.)							
1894	Plot 9, ...	Spe. nitrogen	1,365	42.53	18.16	29.43	4.53	5.35
1895	9, ...	"	1,583	41.40	20.43	28.65	3.40	6.12
1897	9, ...	"	1,842	38.09	18.95	32.98	4.61	5.37
1898	9, ...	"	6,018	44.40	20.72	26.33	2.94	5.61
	Average,			**41.61**	**19.56**	**29.35**	**3.87**	**5.61**

TABLE 38.—CONTINUED.

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	Laboratory No.	Percentage composition of soy beans calculated on water-free substance. Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Dis. boneblack, 320 lbs. *Mur. of potash, 160 lbs.* *Sul. of ammonia, 120 lbs.* (*nitrogen, 25 lbs.*)			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1895	Plot 10, . . .	Spe. nitrogen	1,584	36.86	21.97	30.95	3.58	6.64
1897	10, . . .	"	1,843	41.45	18.41	30.31	4.58	5.25
1898	10, . . .	"	6,019	41.64	21.40	28.03	3.48	5.45
	Average,			**39.99**	**20.59**	**29.76**	**3.88**	**5.78**
	Dis. boneblack, 320 lbs. *Mur. of potash, 160 lbs.* *Sul. of ammonia, 240 lbs.* (*nitrogen, 50 lbs.*)							
1895	Plot 11, . . .	Spe. nitrogen	1,585	37.71	21.58	31.40	3.38	5.93
1897	11, . . .	"	1,844	41.93	18.22	30.15	4.47	5.23
1898	11, . . .	"	6,020	42.54	21.82	27.15	2.87	5.62
	Average,			**40.73**	**20.54**	**29.57**	**3.57**	**5.59**
	Dis. boneblack, 320 lbs. *Mur. of potash, 160 lbs.* *Sul. of ammonia, 360 lbs.* (*nitrogen, 75 lbs.*)							
1895	Plot 12, . . .	Spe. nitrogen	1,586	39.82	20.71	29.08	3.49	6.90
1897	12, . . .	"	1,845	42.12	18.00	29.33	4.73	5.82
1898	12, . . .	"	6,021	42.05	21.77	26.72	3.38	6.08
	Average,			**41.33**	**20.16**	**28.38**	**3.87**	**6.26**

TABLE 39.—*Effects of nitrogenous fertilizers upon soy beans (seeds).*

[The details of the experiments may be found in the Reports of the Station for the years in which the several experiments were made or for the year following.]

Year.	Plot No. and kind and amount of fertilizer per acre.	Kind of experiment.	YIELD OF DRY MATTER AND NUTRIENTS IN SOY BEANS PER ACRE.					
			Water free substance.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.
	Nothing.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1895	Plots 0, 00, . .	Spe. nitrogen	581	216	116	163	19	67
1897	0, 00, . .	"	206	78	36	69	13	10
1898	0, 00, . .	"	449	202	88	118	17	24
	Average,		412	165	80	117	16	34
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen, —							
1895	Plots 6*a*, 6*b*, . .	Spe. nitrogen	721	264	158	225	25	49
1897	6*a*, 6*b*, . .	"	314	121	56	106	14	17
1898	6*a*, 6*b*, . .	"	800	339	171	217	27	46
	Average,		612	241	128	183	22	38
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen (diff. forms), 25 lbs.							
1895	Plots 7, 10, . .	Spe. nitrogen	760	281	166	233	26	54
1897	7, 10, . .	"	390	155	71	125	18	21
1898	7, 10, . .	"	727	321	154	196	22	40
	Average,		626	252	130	184	22	38
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen (diff. forms), 50 lbs.							
1895	Plots 8, 11, . .	Spe. nitrogen	900	347	194	275	30	54
1897	8, 11, . .	"	353	140	64	109	20	20
1898	8, 11, . .	"	866	378	182	234	23	48
	Average,		706	288	147	206	24	41
	Dis. boneblack, 320 lbs. Mur. of potash, 160 lbs. Nitrogen (diff. forms), 75 lbs.							
1895	Plots 9, 12, . .	Spe. nitrogen	921	374	189	266	32	60
1897	9, 12, . .	"	414	166	77	129	19	23
1898	9, 12, . .	"	811	351	182	215	26	47
	Average,		715	297	146	203	26	43

A discussion of the experiments and analyses here detailed is given on pages 113 to 154, and the results and conclusions are summarized on pages 155 to 159.

DIGESTION EXPERIMENTS WITH SHEEP.

BY C. S. PHELPS.

In estimating the values of different feeding stuffs, by chemical analysis as well as in connection with feeding experiments conducted by the Station, very useful information is gained by testing the actual digestibility of the materials. Only that part of the food which the animal can digest is of value for purposes of nutrition. We need to know, therefore, not only the chemical composition of a fodder article, but also the proportions of the various nutrients which are digested, in order to judge of its nutritive value. From experiments made elsewhere, it has been found that all animals of the same class, such as ruminants, digest their food in practically the same way, and that the digestibility of a given feeding stuff by sheep may be taken as a nearly accurate measure of the digestibility of the same fodder by a cow or steer. As the care and labor required in digestion experiments with sheep is much less than with larger animals, sheep have been used in the digestion experiments here reported.

The method of conducting these experiments is described in the Annual Report of the Station for 1894, pages 107-109. For the present purpose the following brief summary will suffice.

The sheep were kept in pens about five feet square, with mangers arranged so as to prevent loss of food by scattering. Each experiment lasted twelve days. The first seven days were devoted to preliminary feeding, during which the feces were not collected and each animal had the run of the pen. At the end of this period the sheep were placed in narrow stalls, where they remained during the five days of the digestion experiment proper, during which the feces were collected in rubber lined bags.

The feeding stuffs, the uneaten residues, and the feces were each weighed and analyzed. The differences between the amounts of organic matter and nutrients in the food eaten and the amounts of the same ingredients in the feces were taken as the measure of the amounts digested. The metabolic products in the feces are here treated as part of the undigested residue of the food.

Digestion experiments with sheep.

In previous reports the distinction between "heats of combustion" and "fuel values" has not been explained as clearly as seems desirable. As the terms are here used the heat of combustion of a given food material is the total energy of that material as determined by burning a given amount of it with oxygen in the bomb calorimeter; while the fuel value of the same material is the energy which can become available to the body when the material is eaten. That is to say, the fuel value is the total heat of combustion of the food less that of the corresponding feces and urine.

In the experiments here reported the heats of combustion of the food and of the feces were determined by the bomb calorimeter, and that of the urine was estimated; the difference between the first and the sum of the last two was taken as the measure of the energy of the food digested, *i. e.*, the fuel value of the food eaten.*

The nitrogenous matter of the digested food is not completely oxidized in the body, but a portion is eliminated in the urine as urea and kindred compounds. The potential energy of these compounds is not available to the body, and is deducted from the energy of the material digested to give the amount of energy available from any given material. The amount of energy in the compounds in urine is roughly calculated in the manner described on page 178 of the Annual Report of this Station for 1896, in the discussion of digestion experiments with men. The assumptions made there give results that are probably rather too low. Late research seems to indicate that a larger factor should be assigned to the fuel value of the nitrogenous matter of the urine.

General conclusions from these experiments will hardly be permissible until more data are available. One point, however, is brought out very clearly. Among the feeding stuffs tested those rich in protein, such as the legumes, are more digestible than those with little protein, such as corn fodder, oat fodder, millet, and the like.

Table 40, which follows, gives a summary of the results of the digestion experiments thus far made with sheep by the Station. These experiments are arranged, according to the character of the feeding stuffs used, under the headings: Milling products (with hay), cured fodders and hays, and green fodders and grasses.

* See Report of the Station for 1897, pages 155, 156.

TABLE 40.—*Coefficients of digestibility of nutrients in different feeding stuffs and groups of feeding stuffs as determined by experiments with sheep.*

FEEDING STUFFS.		No. of experiments.	Protein, N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Organic matter.	Energy.
Milling products (with hay).			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Bran, corn meal, and hay,	Min.	4	48.0	60.6	71.5	45.6	62.7	57.6
	Max.	4	62.1	72.9	80.1	60.7	72.8	67.9
	Avg.	4	**55.0**	**68.5**	**76.4**	**55.3**	**69.0**	**64.3**
Bran, corn meal, linseed meal, oat and pea meal, and hay,	Min.	4	71.2	64.7	73.6	59.0	70.1	63.6
	Max.	4	77.1	73.4	77.0	69.2	75.0	70.3
	Avg.	4	**73.4**	**70.5**	**74.8**	**62.5**	**71.6**	**66.0**
Soy bean meal and timothy hay,	Min.	8	75.8	71.1	60.9	55.8	65.4	61.3
	Max.	8	80.0	77.4	71.8	69.5	73.7	68.7
	Avg.	8	**77.7**	**73.6**	**66.1**	**61.3**	**69.1**	**64.3**
Coarse bran and rowen hay, mixed grasses,	Min.	4	67.5	54.9	65.2	44.7	62.0	57.0
	Max.	4	71.5	66.0	69.4	56.4	67.1	62.4
	Avg.	4	**69.6**	**60.9**	**67.2**	**49.0**	**63.7**	**58.6**
No. 2 wheat middlings and rowen hay, mixed grasses,	Min.	4	70.6	68.9	71.0	54.3	68.5	63.7
	Max.	4	76.1	71.7	73.0	58.6	69.2	64.4
	Avg.	4	**72.9**	**70.7**	**71.8**	**55.5**	**68.9**	**64.0**
Fine rowen and Cleveland flax meal,	Min.	3	76.8	49.4	56.1	68.7	65.4	56.5
	Max.	3	81.5	55.9	63.6	70.1	70.2	61.1
	Avg.	3	**78.8**	**53.4**	**60.4**	**69.6**	**67.9**	**59.0**
Fine rowen and Quaker oat feed,	Min.	3	66.7	38.8	61.3	54.1	60.1	57.2
	Max.	3	71.0	68.8	65.6	58.3	63.3	59.8
	Avg.	3	**68.5**	**56.3**	**62.8**	**55.6**	**61.3**	**58.4**
Experiments with soy bean meal and timothy hay calculated for digestibility of soy bean meal alone, . .		..	85.8	84.9	73.4	....	78.0	72.5
Experiments with coarse bran and rowen hay of mixed grasses calculated for digestibility of coarse bran alone, ...		..	70.3	72.2	67.2	16.2	61.3	56.6
Experiments with No. 2 wheat middlings and rowen hay of mixed grasses calculated for digestibility of wheat middlings alone, ...		..	75.7	88.8	75.6	30.2	71.3	67.3
Experiments with Cleveland flax meal and fine rowen calculated for digestibility of Cleveland flax meal alone, .		..	85.4	83.1	57.0	92.8	76.1	61.0
Experiments with Quaker oat feed and fine rowen calculated for digestibility of oat feed alone, ...		..	62.8	54.8	42.6	67.2	52.4	52.7
Cured fodders and hays.								
Rowen hay, mixed grasses chiefly Kentucky blue grass,	Min.	4	67.6	44.0	62.6	65.4	63.5	57.1
	Max.	4	70.2	50.5	67.7	68.2	66.7	60.9
	Avg.	4	**69.1**	**46.2**	**65.1**	**66.5**	**65.2**	**58.9**
Rowen hay, mostly timothy,	Min.	4	66.1	48.2	60.9	62.0	62.0	58.3
	Max.	4	69.4	50.8	64.9	73.4	67.2	60.9
	Avg.	4	**68.0**	**49.5**	**63.4**	**66.5**	**64.4**	**59.3**
Rowen hay, mixed grasses,	Min.	8	67.7	43.9	60.4	62.5	62.7	56.8
	Max.	8	73.7	50.6	68.5	72.4	68.1	62.4
	Avg.	8	**70.8**	**46.9**	**64.8**	**66.2**	**65.5**	**59.5**
Rowen hay, clover, field cured,	Min.	2	60.3	58.3	63.1	47.6	58.1	53.0
	Max.	2	65.1	60.4	64.1	50.7	60.5	54.5
	Avg.	2	**62.7**	**59.4**	**63.6**	**49.2**	**59.3**	**53.8**

TABLE 40.—CONTINUED.

FEEDING STUFFS.		No. of experiments.	Protein, N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Organic matter.	Energy.
Cured fodders and hays.			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Rowen hay, clover, barn cured,	Min.	2	64.7	59.9	61.7	44.7	58.0	53.0
	Max.	2	69.1	60.5	62.2	46.4	59.7	54.1
	Avg.	2	66.9	60.2	62.0	45.6	58.9	53.6
Scarlet clover hay, field cured,	Min.	4	67.8	45.9	57.3	39.8	52.9	48.3
	Max.	4	68.9	52.4	62.7	47.3	56.6	51.9
	Avg.	4	68.3	49.2	60.0	43.7	54.8	50.0
Scarlet clover hay, barn cured,	Min.	3	67.2	29.5	59.8	42.8	56.2	50.0
	Max.	3	73.2	42.3	63.9	48.9	57.8	52.1
	Avg.	3	69.3	34.9	61.8	46.2	57.2	51.2
Oat hay (early seed),	Min.	4	52.3	60.5	50.5	39.4	47.9	44.1
	Max.	4	57.7	63.0	53.9	46.8	52.6	48.9
	Avg.	4	54.2	61.9	52.0	43.5	50.1	46.3
Green fodders and grasses.								
Scarlet clover fodder,	Min.	3	76.7	62.9	74.1	54.1	68.5	63.7
	Max.	3	77.5	69.3	74.9	57.9	69.8	64.3
	Avg.	3	77.1	66.5	74.5	56.1	69.1	64.1
Barley fodder,	Min.	6	66.7	48.2	69.3	47.2	62.2	57.8
	Max.	6	73.1	63.1	76.3	66.4	70.8	66.4
	Avg.	6	70.7	56.3	72.2	59.1	67.7	62.4
Barley and pea fodder,	Min.	4	73.2	54.5	55.8	37.6	55.2	49.4
	Max.	4	81.1	64.8	75.8	61.4	71.3	65.2
	Avg.	4	75.9	59.1	68.5	52.4	65.7	60.0
Oat and pea fodder,	Min.	7	67.8	54.9	56.2	48.2	57.8	53.4
	Max.	7	82.7	74.3	67.1	67.4	70.2	66.1
	Avg.	7	76.3	67.0	63.9	55.5	63.9	59.7
Oat fodder,	Min.	5	67.8	67.5	60.0	43.5	56 5	53.2
	Max.	5	75.7	72.3	66.9	62.6	65.4	61.9
	Avg.	5	72.6	69.5	62.8	54.6	61.8	58.3
Barnyard millet fodder,	Min.	3	45.0	59.8	64.4	58.8	61.8	57.8
	Max.	3	57.3	71.8	68.4	63.2	65.6	62.8
	Avg.	3	50.5	67.7	67.0	61.5	64.2	60.9
Hungarian fodder,	Min.	4	61.0	59.8	66.3	70.3	67.6	63.6
	Max.	4	71.8	85.1	71.7	76.1	73.8	71.3
	Avg.	4	65.3	72.3	68.9	72.8	70.1	67.0
Soy bean fodder,	Min.	12	67.7	30.7	68.7	38.5	61.0	55.4
	Max.	12	80.5	61.5	80.7	55.5	68.7	63.4
	Avg.	12	75.5	48.1	75 0	46.1	65.3	59.7
Clover rowen,	Min.	2	61.4	60.0	63.9	51.5	59.7	55.6
	Max.	2	62.3	61.5	66.7	53.6	61.9	57.3
	Avg.	2	61.9	60.8	65.3	52.6	60.8	56.5
Rowen, mixed grasses and clover,	Min.	2	64.9	54.0	71.3	61.8	67.0	61.3
	Max.	2	69.9	56.3	71.9	63.3	67.8	62.3
	Avg.	2	67.4	55.2	71.6	62.6	67.4	61.8
Rowen, mostly timothy,	Min.	2	71.5	50.9	67.3	60.0	65.3	58.8
	Max.	2	71 9	54.8	68.2	67 6	67.5	61.7
	Avg.	2	71.7	52.8	67.8	63.8	66.4	60.3
Sweet corn fodder,	Min.	12	52.5	62.4	73.3	53.6	67.5	64.5
	Max.	12	68.7	82.1	82.4	72.2	78.8	75.1
	Avg.	12	61.6	74.8	76.8	60.2	71.8	68.0
Cow pea fodder,	Min.	4	72.7	56.3	76.4	57.1	72.1	66.1
	Max.	4	77.3	62.5	84.2	62.4	76.0	71.2
	Avg.	4	75.6	59.4	80.6	58.6	74.0	68.6
Canada pea fodder,	Min.	2	81.1	50.0	70.8	62.4	71.0	64.3
	Max.	2	83.0	54.8	71.3	62.4	71.7	65.0
	Avg.	2	82.1	52.4	71.1	62.4	71.4	64.7

The details of experiments Nos. 1-9 will be found in the Annual Report for 1894; Nos. 10-27 in the Report for 1895, and Nos. 28-44 in the Report for 1896. The detailed account of experiments 45-55 follows.

Digestion Experiment No. 45.

Sweet corn fodder (fed green).— The description of this experiment was given on page 255, and the results summarized in table 72, page 251 of the Report of 1896. The details are given on page 210 of this report.

Digestion Experiment No. 46.

Oat and pea fodder (fed green).— The experiment began July 15, 1897, and continued 14 days. The feces were collected for the five days from July 24, at 6 P.M. to July 29, at 6 P.M. Two samples were taken, one July 17, the other July 24. In the first sample the oat seed was formed but was quite soft; peas nearly out of bloom. Many pods and seeds were well formed. The bottom leaves of the peas were slightly moldy or dead. In the second sample the oat seeds were somewhat firm and the husks were turning white, while the leaves were more or less rusty. The peas were past bloom and many of the pods were hard. The fodder was badly lodged from a recent storm which prevented taking another sample July 22 as was planned. The first three days each animal, sheep A, B, C, and D, was fed daily 3,000 grams of the fodder, in two feeds of 1,500 grams each; and the remaining eleven days of the experiment, 2,800 grams of the fodder were fed to each animal daily, in two equal portions. Some refuse was left by each animal. Sheep A left very little (none at all after July 24); B and C left so much that they were discarded from the experiment. The refuse left by sheep D was saved from July 17 to the end of the experiment.

Digestion Experiment No. 47.

Soy bean fodder (fed green). The experiment began Aug. 24, 1897, and continued twelve days. The feces were collected for the five days from Aug. 30 at 6 P.M. to Sept. 4 at 6 P.M. The first sample was taken Aug. 28, when the beans were past bloom, with pods well formed and seeds beginning to develop; the stalks were 2½ ft. to 3 ft. high, and the fodder was in excellent condition for feeding. At the time of taking the second sample most of the pods and some seeds were formed. A very few leaves were a trifle rusty or dry, but otherwise the fodder was in good condition for feeding. Each animal, sheep A, B, C, and D, was fed 3,000 grams of the fodder daily, in two equal feeds. The sheep left some refuse which was saved

Digestion Experiment No. 48.

Sweet corn fodder (fed green).—The experiment began Sept 3, 1897, and continued twelve days. The feces were collected for the five days from Sept. 20 at 5.30 P.M. to Sept. 25 at 6 P.M. The corn was of the "Branching Sweet" variety. Two samples were taken, one Sept. 17, and the other Sept. 20, 1897. At the time the first sample was taken the corn was of good growth, the tassels and silk were nearly dry, the leaves and stalks were a trifle rusty, the ears were well formed and the corn was in the milk stage. The second sample was the same as the first, with the exception that the seeds were slightly hardened and the bottom leaves of the stalks were becoming dry. Each animal, sheep A, B, C, and D, was fed daily 3,000 grams of the fodder in two equal feeds. Each of the four sheep left refuse. That left by sheep C and D was collected and saved, but the amount left by sheep A and B was so large that the animals were discarded from the experiment.

Digestion Experiment No. 49.

Barley and pea fodder (fed green).—The experiment began Oct. 11, 1897, and continued thirteen days. The feces were collected for the five days from Oct. 18 at 5 P.M. to Oct. 23 at 5 P.M. Two samples were taken, one Oct. 15, the other Oct. 19. In the first the barley was of fair growth, the heads and rudiments of seeds were formed and the leaves were more or less rusty or dead. The peas were not yet in bloom, but were in good condition for feeding. In the second the barley was in about the same condition as in the first, except that the heads were grown to the early seed stage. Buds were well formed on the peas, but none were in blossom. During the first four days of the experiment each sheep was fed 3,000 grams of the fodder daily in two equal feeds, and the remaining nine days 2,800 grams of the fodder was fed to each sheep daily in two equal feeds. Both animals left some refuse, but the quantity was so very small that it was left out of account in computing the results.

Digestion Experiment No. 50.

Barley fodder, fed green. The experiment began Oct. 11, 1897, and continued thirteen days. The feces were collected for the five days from Oct. 18 at 5 P. M. to Oct. 23 at 5 P. M. At the time of taking the first, Oct. 15, the barley was in fair growth, with heads well developed and seeds forming. The bottom leaves were either rusty or dead, but otherwise it was in fair condition for feeding. The second sample, taken Oct. 19, was in practically the same condition as the first. Each animal, sheep C and D, was fed 2,800 grams of the fodder daily for the first four days, and for the last nine days 3,000 grams were fed daily in two equal feeds. Both sheep left a small amount of refuse, which was saved, but finally discarded as being too small to take into account.

Digestion Experiment No. 51.

Rowen, mixed grasses, nearly free from clover. The experiment began Dec. 8, 1897, and continued twelve days. The feces were collected for the five days from the evening of Dec. 15 to the evening of Dec. 20. The rowen was sampled Dec. 9, from a lot weighed out for eleven days' rations. Each animal, sheep A, B, C, and D, was fed daily 700 grams of the rowen cut into pieces about one inch long. Sheep A, B, and C ate well during the whole test. Sheep D left about one-fourth of his ration the evening of Dec. 18. During the remainder of the experiment he ate all but a small quantity. The refuse was assumed to be of the same composition as the rowen fed.

Digestion Experiment No. 52.

Cleveland flax-meal with fine rowen. The rowen was the same as was used in experiment No. 51, and was sampled from a 50-pound lot cut into pieces about one inch long. The flax-meal was sampled from an 80-pound lot out of which rations for twelve days were weighed. The experiment began Jan. 31, 1898, and continued twelve days. Each animal, sheep A, B, C, and D, was fed daily 200 grams of the rowen. Sheep A and C were each fed 200 grams and sheep B and D 100 grams of flax-meal daily. Sheep B did not eat the ration well and was discarded from the experiment. The feces were collected for the five days from the evening of Feb. 7 to the evening of Feb. 12.

Digestion Experiment No. 53.

Quaker oat feed with fine rowen. The rowen was the same as was used in experiment No. 51 and was sampled Mar. 2 from a 50-pound lot cut into pieces about one inch long. The Quaker oat feed was from a lot of 90 pounds, and was the same as that used in cow-feeding experiment No. 47. The experiment began Mar. 2, 1898, and continued twelve days. Each animal, sheep A, C, and D, was fed daily 500 grams of rowen and 500 grams of Quaker oat feed. The feces were collected for the five days from the evening of Mar. 9 to the evening of Mar. 14. The experiment was normal throughout.

Digestion experiment No. 45. Sweet corn fodder (fed green).

Composition of feeding stuffs and of feces.

Laboratory No.		Water.	Protein N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.	Heat of combustion.*
	Feeding stuff.								
	Sweet corn fodder.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories
1,729	Sample 1, .	82.6	1.8	.5	9.9	4.0	1.2	16.2	772
1,730	Sample 2, .	81.0	1.8	.6	10.9	4.5	1.2	17.8	854
	Average,	81.8	1.8	.6	10.4	4.3	1.2	17.0	813
	Feces.								
1,734	Sheep C, ...	7.2	11.2	2.5	46.3	23.8	9.0	83.8	4,330
1,735	Sheep D, . . .	7.5	11.9	2.3	42.9	28.1	7.3	85.2	4,392

* Per gram as determined.

DIGESTION EXPERIMENT NO. 45.—CONTINUED.

Weights of food eaten, and of feces for five days, and weights and per cents of nutrients digested.

	Total weight.	Protein N. ×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.
Eaten in 5 days.	Grams.	Grams.	Grams.	Grams.	Grams	Grams.	Grams.
Sheep C and D, fed each,	13,700	247	69	1,425	589	164	2,330
Feces for 5 days.							
Sheep C, . . .	816	91	21	378	194	73	684
Sheep D, . . .	870	104	20	373	244	64	741
Amount digested.							
Sheep C, . . .	12,884	156	48	1,047	395	91	1,646
Sheep D, . . .	12,830	143	49	1,052	345	100	1,589
Per cent. digested.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Sheep C, . . .	......	63.2	69.6	73.5	67.1	55.5	70.6
Sheep D, . . .	......	57.9	71.0	73.8	58.6	61.0	68.2
Average,	......	**60.3**	**70.3**	**73.7**	**62.9**	**58.3**	**69.4**

Heat of combustion of food for five days, and total available energy.

	HEAT OF COMBUSTION.				Total available energy.	Per cent. available energy.
	Of food eaten.	Of feces.	Of food digested.	Of urine. Estimated.		
	Calories.	Calories.	Calories.	Calories.	Calories.	Per cent.
Sheep C, ...	11,138	3,533	7,605	136	7,469	67.0
Sheep D, ...	11,138	3,821	7,317	124	7,193	64.5
Average, . . .	......	......	......	......	......	**65.7**

DIGESTION EXPERIMENT NO. 46. OAT AND PEA FODDER (FED GREEN).

Composition of feeding stuffs and feces.

Laboratory No.		Water.	Protein. N. ×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.	Heat of combustion.*
	Feeeing stuff.								
	Oats and Peas.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories
1,881	Sample 1, . .	74.4	2.8	1.0	12.0	7.9	1.9	23.7	1,133
1,882	Sample 2, . .	74.3	3.2	.9	11.7	7.8	2.1	23.6	1,136
	Average,	**74.4**	**3.0**	**.9**	**11.8**	**7.9**	**2.0**	**23.7**	**1,134**
	Feces.								
1,864	Sheep A, . . .	5.8	8.3	3.3	37.4	34.7	10.5	83.7	4,264
1,863	Sheep D, . . .	5.6	7.5	3.4	38.9	34.1	10.5	83.9	4,298
	Uneaten residue.								
1,887	Sheep D, . . .	5.8	6.1	4.1	34.3	37.6	12.1	82.1	3,935

* Per gram as determined.

DIGESTION EXPERIMENT NO. 46.—CONTINUED.

Weights of food eaten, and of feces for five days, and weights and per cents. of nutrients digested.

	Total weight.	Protein. N. × 6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.
Eaten in 5 days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A and D, fed each,	14,000	420	126	1,652	1,106	280	3,304
Uneaten residue, D, .	104	6	4	36	39	13	85
Actually eaten, A, .	14,000	420	126	1,652	1,106	280	3,304
Actually eaten, D, .	13,896	414	122	1,616	1,067	267	3,219
Feces for 5 days.							
Sheep A, . . .	1,623	135	54	607	563	170	1,359
Sheep D, . . .	1,618	121	55	629	552	170	1,357
Amounts digested.							
Sheep A, . . .	12,377	285	72	1,045	543	110	1,945
Sheep D, . . .	12,278	293	67	987	515	97	1,862
Per cent. digested.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Sheep A, . . .		67.8	57.1	63.3	49.0	39.2	58.9
Sheep D, . . .		70.7	54.9	61.1	48.2	36.3	57.8
Average,		**69.2**	**56.0**	**62.2**	**48.6**	**37.3**	**58.3**

Heat of combustion of food for five days, and total available energy.

	Heats of combustion.				Total available energy.	Per cent. available energy.
	Of food eaten.	Of feces.	Of food digested.	Of urine. Estimated.		
	Calories.	Calories.	Calories.	Calories.	Calories.	Per cent.
Sheep A, ...	15,876	6,920	8,956	248	8,708	54.9
Sheep D, ...	15,467	6,954	8,513	255	8,258	53.4
Average, ...	......	......	......	.....	......	**54.1**

DIGESTION EXPERIMENT NO. 47. SOY BEAN FODDER (FED GREEN).

Composition of feeding stuffs and feces.

Laboratory No.		Water.	Protein. N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.	Heat of combustion.*
	Feeding stuff.								
	Soy bean fodder.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories
1,883	Sample 1, . .	77.0	3.4	.7	10.4	6.3	2.2	20.8	1,003
1,884	Sample 2, . .	76.4	3.7	.7	11.0	6.1	2.1	21.5	1,031
	Average,	**76.7**	**3.6**	**.7**	**10.7**	**6.2**	**2.1**	**21.2**	**1,017**
	Feces.								
1,865	Sheep A, ...	3.8	8.4	4.4	21.7	36.9	24.8	71.4	3,800
1,866	Sheep B, ...	3.8	8.4	4.1	22.2	37.2	24.3	71.9	3,764
1,867	Sheep C, ...	4.1	9.7	4.8	25.8	34.8	20.8	75.1	3,930
1,868	Sheep D, ...	3.7	9.4	5.6	25.8	33.1	22.4	73.9	3,947
	Uneaten residue.								
1,888	Sheep B, ...	5.1	7.0	1.0	31.2	39.8	15.9	79.0	3,714
1,891	Sheep C, ...	5.0	5.3	.6	33.3	51.3	4.5	90.5	4,216
1,889	Sheep D, ...	4.8	5.6	.7	33.6	49.0	6.3	88.9	4,162

* Per gram as determined.

Weights of food eaten, and of feces for five days, and weights and per cents. of nutrients digested.

	Total weight.	Protein. N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.
Eaten in 5 days.							
Sheep A, B, C, & D, fed	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
each, . . .	15,000	540	105	1,605	930	315	3,180
Uneaten residue, B, .	44	3	0	14	18	7	35
Uneaten residue, C, .	46	2	0	15	24	2	41
Uneaten residue, D, .	138	8	1	46	68	9	123
Actually eaten, A, .	15,000	540	105	1,605	930	315	3,180
Actually eaten, B, .	14,956	537	105	1,591	912	308	3,145
Actually eaten, C, .	14,954	538	105	1,590	906	313	3,139
Actually eaten, D, .	14,862	532	104	1,559	862	306	3,057
Feces for 5 days.							
Sheep A, ...	1,535	129	68	333	566	381	1,096
Sheep B, ...	1,383	116	57	307	515	336	995
Sheep C, ...	1,466	142	70	378	510	305	1,100
Sheep D, ...	1,294	122	72	334	428	290	956
Amounts digested.							
Sheep A, ...	13,465	411	37	1,272	364	Sheep	2,084
Sheep B, ...	13,573	421	48	1,284	397	had	2,150
Sheep C, ...	13,488	396	35	1,212	396	salt.	2,039
Sheep D, ...	13,568	410	32	1,225	434	....	2,101
Per cent. digested.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.		Per cent.
Sheep A, ...	89.7	76.1	35.2	79.2	39.1	....	65.5
Sheep B, ...	90.8	78.4	45.7	80.7	43.5	....	68.4
Sheep C, ...	90.2	73.6	33.3	76.2	43.7	....	65.0
Sheep D, ...	91.2	77.1	30.7	78.5	50.3	....	68.7
Average,	**90.5**	**76.2**	**36.0**	**78.6**	**44.3**	....	**66.8**

DIGESTION EXPERIMENT NO. 47.—CONTINUED.

Heat of combustion of food for five days and total available energy.

	Heats of combustion.				Total available energy.	Per cent. available energy.
	Of food eaten.	Of feces.	Of food digested.	Of urine. Estimated.		
	Calories.	Calories.	Calories.	Calories.	Calories.	Per cent.
Sheep A,	15,255	5,833	9,422	470	8,952	58.6
Sheep B,	15,092	5,206	9,886	467	9,419	62.4
Sheep C,	15,061	5,761	9,300	467	8,833	58.6
Sheep D,	14,681	5,107	9,574	463	9,111	62.0
Average,	....	....	....	....	....	60.4

DIGESTION EXPERIMENT NO. 48. SWEET CORN FODDER (FED GREEN).

Composition of feeding stuffs and feces.

Laboratory No.		Water.	Protein. N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.	Heat of combustion.*
	Feeding stuff.								
	Branching sweet corn.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories
1,885	Sample 1,	78.5	1.9	.6	14.1	3.7	1.2	20.3	932
1,886	Sample 2,	76.6	1.7	.7	16.2	3.6	1.2	22.2	1,008
	Average,	77.5	1.8	.7	15.2	3.6	1.2	21.3	970
	Feces.								
1,869	Sheep C,	4.0	10.4	4.4	43.8	25.8	11.6	84.4	4,189
1,870	Sheep D,	4.0	11.1	2.7	45.3	21.8	15.1	80.9	4,073
	Uneaten residue.								
1,890	Sheep C,	4.9	7.1	1.9	59.5	23.2	3.4	91.7	4,195
1,892	Sheep D,	4.8	4.4	1.8	32.2	51.7	5.1	90.1	4,106

* Per gram as determined.

DIGESTION EXPERIMENT No. 48.—CONTINUED.

Weights of food eaten, and of feces for five days, and weights and per cents. of nutrients digested.

	Total weight.	Protein. N. ×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.
Eaten in five days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep C and D, fed each,	15,000	270	105	2,280	540	180	3,195
Uneaten residue, C, .	185	13	4	110	43	6	170
Uneaten residue, D, .	47	2	1	15	24	2	42
Actually eaten, C, .	14,815	257	101	2,155	512	174	3,025
Actually eaten, D, .	14,953	268	104	2,250	531	178	3,153
Feces for five days.							
Sheep C, . . .	876	91	38	384	226	102	739
Sheep D, . . .	921	102	25	417	201	139	745
Amounts digested.							
Sheep C, . . .	13,939	166	63	1,771	286	72	2,286
Sheep D, . . .	14,032	166	79	1,833	330	39	2,408
Per cent. digested.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent
Sheep C, . . .	......	64.6	62.4	82.2	55.8	41.3	75.6
Sheep D, . . .	......	61.9	76.0	81.5	62.1	21.9	76.4
Average,	......	**63.2**	**69.2**	**81.8**	**58.9**	**31.6**	**76.0**

Heat of combustion of food for five days, and total available energy.

	Heats of combustion.				Total available energy.	Per cent. available energy.
	Of food eaten.	Of feces.	Of food digested.	Of urine. Estimated.		
	Calories.	Calories.	Calories.	Calories.	Calories.	Per cent.
Sheep C, ...	13,774	3,668	10,106	224	9,882	71.7
Sheep D, ...	14,357	3,751	10,606	233	10,373	72.2
Average, ...	......	......	......	....	......	**71.9**

DIGESTION EXPERIMENT No. 49. BARLEY AND PEA FODDER (FED GREEN).

Composition of feeding stuffs and feces.

Laboratory No.		Water.	Protein. N. ×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.	Heat of combustion.*
	Feeding stuff.								
	Barley and pease.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories
1,913	Sample 1, . .	75.4	4.0	1.0	12.1	5.7	1.8	22.8	1,073
1,914	Sample 2, . .	74.1	4.0	1.0	12.7	6.1	2.1	23.8	1,108
	Average,	**74.7**	**4.0**	**1.0**	**12.4**	**5.9**	**2.0**	**23.3**	**1,091**
	Feces.								
1,917	Sheep A, ...	5.2	12.2	4.9	37.9	28.1	11.7	83.1	4,366
1,918	Sheep B, ...	3.8	12.3	5.4	38.0	29.1	11.4	84.8	4,489

* Per gram as determined.

DIGESTION EXPERIMENT NO. 49.—CONTINUED.

Weights of food eaten, and of feces for five days, and per cents. of nutrients digested.

	Total weight.	Protein. N. × 6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.
Eaten in five days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, and B, each,	14,000	560	140	1,736	826	280	3,262
Feces for five days.							
Sheep A, . . .	1,136	139	56	430	319	133	944
Sheep B, . . .	1,105	136	60	420	321	126	937
Amounts digested.							
Sheep A, . . .	12,864	421	84	1,306	507	147	2,318
Sheep B, . . .	12,895	424	80	1,316	505	154	2,325
Per cent. digested.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Sheep A, . . .		75.2	60.0	75.2	61.4	52.5	71.1
Sheep B, . . .		73.9	57.1	75.8	61.1	55.0	71.3
Average,		**74.5**	**58.5**	**75.5**	**61.2**	**53.7**	**71.2**

Heat of combustion of food for five days, and total available energy.

	HEATS OF COMBUSTION.				Total available energy.	Per cent. available energy.
	Of food eaten.	Of feces.	Of food digested.	Of urine. Estimated		
	Calories.	Calories.	Calories.	Calories.	Calaries.	Per cent.
Sheep A, ...	15,274	4,960	10,314	365	9,949	65.1
Sheep B, ...	15,274	4,960	10,314	360	9,954	65.2
Average, ...	......	......	.....	......	......	**65.2**

DIGESTION EXPERIMENT NO. 50. BARLEY FODDER (FED GREEN).

Composition of feeding stuffs and feces.

Laboratory No.		Water.	Protein. N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.	Heat of combustion.*
	Feeding stuff.								
	Barley fodder.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct	Per ct.	Calories
1,915	Sample 1, . .	73.0	3.1	.8	15.1	6.0	2.0	25.0	1,138
1,916	Sample 2, . .	71.3	3.2	.9	16.0	6.6	2.0	26.7	1,231
	Average,	**72.2**	**3.2**	**.8**	**15.5**	**6.3**	**2.0**	**25.8**	**1,185**
	Feces.								
1,919	Sheep C, ...	3.3	9.0	4.0	40.3	31.9	11.5	85.2	4,433
1,920	Sheep D, ...	3.8	11.8	4.5	42.7	24.7	12.5	83.7	4,383

* Per gram as determined.

DIGELTION EXPERIMENT No. 50.— CONTINUED.

Weights of food eaten, and of feces for five days, and per cents. of nutrients digested.

	Total weight.	Protein. N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.
Eaten in 5 days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep C, and D, each,	14,000	448	112	2,170	882	280	3,612
Feces for 5 days.							
Sheep C, . . .	1,460	131	58	588	466	168	1,243
Sheep D, . . .	1,262	149	56	539	312	158	1,056
Amounts digested.							
Sheep C, . . .	12,540	317	54	1,582	416	112	2,369
Sheep D, . . .	12,738	299	56	1,631	570	122	2,556
Per cent. digested.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Sheep C, . . .	....	70.8	48.2	72.9	47.2	40.0	65.6
Sheep D, . . .	....	66.7	50.0	75.2	64.6	43.6	70.8
Average,	....	**68.7**	**49.1**	**74.0**	**55.9**	**41.8**	**68.2**

Heat of combustion of food for five days, and total available energy.

	Heats of combustion.				Total available energy.	Per cent. available energy.
	Of food eaten.	Of feces.	Of food digested.	Of urine Estimated.		
	Calories.	Calories.	Calories.	Calories.	Calories.	Per cent.
Sheep C, ...	16,590	6,472	10,118	276	9,842	59.3
Sheep D, ...	16,590	5,531	11,059	260	10,799	65.1
Average, ...	....	....	....	....	....	**62.2**

DIGESTION EXPERIMENT No. 51. FINE ROWEN HAY.

Composition of feeding stuffs and feces.

Laboratory No.		Water.	Protein. N.× 6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.	Heat of combustion.*
	Feeding stuff.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct	Per ct.	Calories
1,940	Fine rowen hay.	12.0	15.3	3.5	37.7	25.1	6.4	81.6	3,962
	Feces.								
1,945	Sheep A, . .	6.8	11.8	5.5	39.9	25.6	10.4	82.8	4,451
1,946	Sheep B, . .	6.8	11.3	5.4	41.0	25.8	9.7	83.5	4,430
1,947	Sheep C, . .	6.6	11.4	5.6	41.5	25.0	9.9	83.5	4,482
1,948	Sheep D, . .	6.6	14.1	5.7	40.9	22.1	10.6	82.8	4,528
	Uneaten residue.								
1,941	Sheep D, . .	8.2	16.1	3.4	38.8	26.3	7.2	84.6	4,110

*Per gram as determined.

DIGESTION EXPERIMENT NO. 51.— CONTINUED.

Weights of food eaten, and of feces for five days, and per cents. of nutrients digested.

	Total weight.	Protein. N. ×6.25.	Fat.	Nitrogen-free extract.	Fiber.	Ash.	Organic matter.
Eaten in five days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, B, C, D, fed each.	3,500	536	123	1,319	878	224	2,856
Uneaten residue, D, .	159	26	5	62	42	11	135
Actually eaten, A, .	3,500	536	123	1,319	878	224	2,856
Actually eaten, B, .	3,500	536	123	1,319	878	224	2,856
Actually eaten, C, .	3,500	536	123	1,319	878	224	2,856
Actually eaten, D, .	3,341	510	118	1,257	836	213	2,721
Feces for five days.							
Sheep A, . . .	1,257	148	69	502	322	131	1,041
Sheep B, . . .	1,276	144	69	523	329	124	1,065
Sheep C, . . .	1,237	141	69	513	309	122	1,032
Sheep D, . . .	1,047	148	60	428	231	111	867
Amounts digested.							
Sheep A, . . .	2,243	388	54	817	556	97	1,815
Sheep B, . . .	2,224	392	54	796	549	104	1,791
Sheep C, . . .	2,263	395	54	806	569	106	1,824
Sheep D, . . .	2,294	362	58	829	605	106	1,854
Per cent. digested.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Sheep A, . . .	......	72.4	43.9	61.9	63.3	42.6	63.6
Sheep B, . . .	......	73.1	43.9	60.4	62.5	45.6	62.7
Sheep C, . . .	......	73.7	43.9	61.1	64.8	46.5	63.9
Sheep D, . . .	......	71.0	49.2	65.9	72.4	48.9	68.1
Average,	......	72.5	45.2	62.3	65.7	45.9	64.6

Heat of combustion of food for five days, and total available energy.

	HEATS OF COMBUSTION.				Total available energy.	Per cent. available energy.
	Of food eaten.	Of feces.	Of food digested.	Of urine. Estimated.		
	Calories.	Calories.	Calories.	Calories.	Calories.	Per cent.
Sheep A, ...	13,867	5,595	8,272	337	7,935	57.2
Sheep B, ...	13,867	5,652	8,215	341	7,874	56.8
Sheep C, ...	13,867	5,544	8,323	343	7,980	57.6
Sheep D.	13,214	4,741	8,473	315	8,158	61.7
Average, ...	......	......	......	....	......	58.3

DIGESTION EXPERIMENT NO. 52. FINE ROWEN HAY AND CLEVELAND FLAX MEAL.

Composition of feeding stuffs and feces.

Laboratory No.		Water.	Protein. N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.	Heat of combustion.*
	Feeding stuff.	Per ct.	Per ct.	Per ct	Per ct.	Per ct.	Per ct.	Per ct.	Calories
1,943	Rowen hay, . .	10.7	16.0	3.8	31.9	30.6	7.0	82.3	3,990
1,935	Cleveland flax meal, .	9.2	38.4	2.6	33.1	12.3	4.4	86.4	4,155
	Feces.								
1,951	Sheep A, . . .	9.5	14.9	4.3	35.7	22.1	13.5	77.0	4,105
1,952	Sheep C, . . .	9.0	13.9	4.9	37.8	23.6	10.8	80.2	4,342
1,953	Sheep D, . .	8.8	13.4	5.0	39.6	22.7	10.5	80.7	4,336

* Per gram, as determined.

Weights of food eaten, and of feces for five days, and per cents. of nutrients digested.

	Total weight.	Protein. N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.
Eaten in five days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, ...	3,000	704	102	969	735	184	2,510
Sheep C, ...	3,000	704	102	969	735	184	2,510
Sheep D, ...	2,500	512	89	804	673	162	2,078
Feces for five days.							
Sheep A, ...	1,042	155	45	372	230	141	802
Sheep C, ...	933	130	46	353	220	100	749
Sheep D, ...	891	119	45	353	202	94	719
Amounts digested,							
Sheep A, ...		549	57	597	505	43	1,708
Sheep C, ...		574	56	616	515	84	1,761
Sheep D, ...		393	44	451	471	68	1,359
Per cent. digested.							
Sheep A, ...		78.0	55.9	61.6	68.7	23.4	68.1
Sheep C, ...		81.5	54.9	63.6	70.1	45.7	70.2
Sheep D, ...		76.8	49.4	56.1	70.0	42.0	65.4
Average,		**78.8**	**53.4**	**60.4**	**69.6**	**37.0**	**67.9**

Heat of combustion of food for five days and total available energy.

	HEATS OF COMBUSTION.				Total available energy.	Per cent. available energy.
	Of food eaten.	Of feces.	Of food digested.	Of urine. Estimated.		
	Calories.	Calories.	Calories.	Calories.	Calories.	Per ct.
Sheep A, ...	12,135	4,277	7,858	652	7,206	59.4
Sheep C, ...	12,135	4,051	8,084	673	7,411	61.1
Sheep D, ...	10,057	3,863	6,194	516	5,678	56.5
Average, ...	......	.....	.....	......	......	**59.0**

DIGESTION EXPERIMENT NO. 53. FINE ROWEN HAY AND QUAKER OAT FEED.

Composition of feeding stuffs and feces.

Laboratory No.		Water.	Protein. N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.	Heat of combustion.*
	Feeding stuff.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories
1,982	Fine rowen hay, .	6.7	13.4	4.2	41.0	27.3	7.4	85.9	4,449
1,944	Quaker oat feed, .	7.9	9.2	2.2	54.5	20.7	5.5	86.6	3,984
	Feces.								
1,954	Sheep A, . . .	7.6	8.7	2.4	44.1	26.1	11.1	81.3	4,062
1,955	Sheep C, . . .	8.8	8.4	5.0	42.0	25.6	10.2	81.0	4,158
1,956	Sheep D, . . .	7.1	9.1	3.0	44.5	26.6	9.7	83.2	4,200

* Per gram as determined.

Weights of food eaten, and of feces for five days, aud per cents. of nutrients digested.

	Total weight.	Protein. N.×6.25.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Organic matter.
Eaten in 5 days.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.
Sheep A, C, and D, each,	5,000	565	160	2,387	1,201	323	4,313
Feces for 5 days.							
Sheep A, ...	2,094	182	50	924	547	232	1,703
Sheep C, ...	1,957	164	98	822	501	200	1,585
Sheep D, ...	2,071	188	62	922	551	201	1,723
Amounts digested.							
Sheep A, . . .	2,906	383	110	1,463	654	91	2,610
Sheep C, . . .	3,043	401	62	1,565	700	123	2,728
Sheep D, . . .	2,929	377	98	1,465	650	122	2,590
Per cent. digested.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Sheep A, . . .	....	67.8	68.8	61.3	54.5	28.2	60.5
Sheep C, . . .	....	71.0	38.8	65.6	58.3	38.1	63.3
Sheep D, . . .	....	66.7	61.3	61.4	54.1	37.8	60.1
Average,	....	**68.5**	**56.3**	**62.8**	**55.6**	**34.7**	**61.3**

Heat of combustion of food for five days and total available energy.

	HEATS OF COMBUSTION.				Total available energy.	Per cent. available energy.
	Of food eaten.	Of feces.	Of food digested.	Of urine. Estimated.		
	Calories.	Calories.	Calories.	Calories.	Calories.	Per cent.
Sheep A, ...	21,083	8,506	12,577	333	12,244	58.1
Sheep C, ...	21,083	8,137	12,946	349	12,597	59.8
Sheep D, ...	21,083	8,698	12,385	328	12,057	57.2
Average, ...	....	....	....	....	....	**58.4**

FEEDING EXPERIMENTS ON THE WINTER FATTENING OF LAMBS.

BY CHAS. E. LYMAN.

(REPORTED BY C. S. PHELPS.)

The investigation here reported was undertaken with the idea of gaining some light on the value of different rations and different feeding stuffs on the winter fattening of lambs. The lambs were separated into three lots. The first and second lot included 10 lambs each. They were mostly selected grade Shropshires, considerably larger and rather more vigorous than the average of our feeding lambs. The third lot consisted of 200 lambs of medium quality, taken from a carload purchased in Chicago. They were range-fed lambs with quite a proportion of the blood of the "down" breeds, and were considered fairly good feeders.

Description of Experiments with Lambs of First and Second Lots. — The feeding materials used in these tests were clover rowen hay of good quality and well ripened corn silage with a large proportion of ears, whole corn of the common Western varieties, fine wheat bran, and pea meal. The last is a by-product from the preparation of split peas, and consists largely of the smaller peas which are culled out and mixed with the hulls, and the whole ground and sold under the name of pea meal.

Lot 1 had the narrow ration, which was planned to consist of three-fourths pea meal and one-fourth corn, with about one

* During the winter of 1897-98, the Station co-operated with Chas. E. Lyman of Middlefield, Conn., in conducting some feeding experiments on the fattening of lambs. Mr. Lyman feeds each winter about 4,000 lambs, which are bought during the fall months in the Buffalo or Chicago markets, and thus has favorable opportunities for selecting desirable stock for feeding experiments. The chief purpose of the experiment was to compare the effects of a ration giving a somewhat wide nutritive ratio, with those of one giving a rather narrow nutritive ratio, for fattening purposes. Two small lots of lambs were used for this part of the experiment. In addition a test was laid out with a large number of lambs, with what was designated as a "business ration," to ascertain the profits of feeding. This ration was considered by Mr. Lyman to be nearly a balanced ration for fattening lambs. Thus there was an opportunity afforded for comparing what is commonly known as a narrow ration, a wide ration, and a "balanced" ration.— W. O. ATWATER.

part clover rowen to two parts of silage by weight. After feeding this ration for a week or ten days it became apparent that the experiment could not be carried out on the lines laid down, if profitable gains were to be expected, as the lambs were not disposing of a satisfactory amount of feed. At the end of about ten days bran was substituted for a part of the pea meal, making the ration one-half pea meal, one-fourth bran, and one-fourth corn.

Lot 2 was fed the wider ration, which consisted of three parts corn and one part pea meal, the corn silage and hay being the same in quality as for Lot 1. The proportion of the grain feeds used in the ration remained the same throughout the experiment. The coarse fodders used consisted of nearly two parts of corn silage to one part of clover rowen for the first period, and two parts of corn silage to one and one-half parts of clover rowen for the second period. The total grain ration for the second period was also increased. The amounts of the various feeding stuffs, and the total nutrients consumed per day, on the average, by the first two lots of lambs for each of the two periods, are shown in the following tables. The proportions of total dry matter and of digestible nutrients were estimated from average figures for composition and digestibility of the several kinds of food materials.

TABLE 41.—*Total weight of different feeding stuffs and of digestible nutrients in daily rations fed to ten lambs of the first lot.*

Feeds used.	Total weight.	Total dry matter.	Digestible nutrients. Protein.	Fat.	Carbo-hydrates.	Nutritive ratio.
Period I—31 days.	lbs.	lbs.	lbs.	lbs.	lbs.	
Corn,	4	3.5	.23	.12	2.61	
Bran,	2	1.8	.24	.05	.77	
Pea meal,	10	9.0	1.68	.06	5.18	
Clover rowen,	9	8.0	.88	.19	3.30	
Silage,	18	4.4	.18	.13	2.54	
		26.7	3.21	.55	14.40	1:4.9
Period II—31 days.						
Corn,	5½	4.8	.32	.17	3.59	
Bran,	5½	4.8	.66	.15	2.12	
Pea meal,	10	9.0	1.68	.06	5.18	
Clover rowen,	7	6.2	.69	.15	2.57	
Silage,	14	3.4	.14	.10	1.97	
		28.2	3.49	.63	15.43	1:4.8

TABLE 42.—*Total weight of different feeding stuffs and of digestible nutrients in daily rations fed to ten lambs of the second lot.*

Feeds used.	Total weight.	Total dry matter.	Digestible nutrients. Protein.	Fat.	Carbohydrates.	Nutritive ratio.
Period I—31 days.	lbs.	lbs.	lbs.	lbs.	lbs.	
Corn, ...	14	12.1	.81	.43	9.13	
Pea meal, ...	4½	4.0	.76	.03	2.33	
Clover rowen, . . .	9	8.0	.88	.19	3.30	
Silage, ...	17	4.2	.17	.12	2.40	
		28.3	2.62	.77	17.16	1 : 7.2
Period II—31 days.						
Corn, ...	17	14.7	.99	.53	11.08	
Pea meal, ...	5½	4.9	.92	.03	2.85	
Clover rowen, . . .	9	8.0	.88	.19	2.40	
Silage, ...	12	3.0	.12	.08	1.69	
		30.6	2.91	.83	18.02	1 : 6.8

Cost of Producing 100 Pounds Gain in Live Weight.—The experiment began December 21. The two lots of 10 lambs each were very nearly of a size, the total weight of the lambs of Lot 1 being 13 pounds more than that of Lot 2. When the experiment began, Lot 1 weighed 882 pounds. On January 21 the weight was 987 pounds, making a gain in 31 days of 105 pounds, or an average of 10½ pounds for each lamb. During the 31 days of the second period the gain in weight was 137 pounds, or 13.7 pounds per lamb.

Lot 2 on December 21 weighed 869 pounds, while on January 21 this lot weighed 1,034 pounds, making a gain of 165 pounds in 31 days, or 16½ pounds per lamb. On February 21 the weight of this lot of lambs was 1,150 pounds, giving a gain of 116 pounds in 31 days, or 11.6 pounds per lamb during the second period. It will be seen that the gains for the second lot, which were fed the wide rations, are considerably larger than for the first lot, which had the narrow ration.

The wide ration (Lot 2) was somewhat more expensive than the narrow ration (Lot 1), but the average cost of 100 pounds of increase was 16 cents less for the lambs fed the wide ration. The following table shows the gains for each period, the daily cost of the rations, and the cost of 100 pounds of increase in live weight:

TABLE 43.—*Pecuniary economy of the different rations fed lots one and two.*

Daily ration. Character and amounts.	Daily ration. Total weight.	Lot No.	Period. No.	Period. Duration.	Total weight of ten lambs at the beginning and end of period.	Gain for period.	Cost of ration per day.	Total cost of producing 100 lbs. gain live weight.
Narrow ration.	lbs.			1897–8.	lbs.	lbs.	cents.	
Concentrated feeds: pea meal, 10; corn, 4; bran, 2,	16	1	1	Dec. 21 to Jan. 21.	882	105	18.0	$5.31
Coarse fodders: clover rowen, 9; silage, 18,	27				987			
Concentrated feeds: pea meal, 10; corn, 5½; bran, 5½,	21	1	2	Jan. 21 to Feb. 21.	987	137	20.1	4.55
Coarse fodders: clover rowen, 7; silage, 14,	21				1,124			
Total,	......	.....	......	....	....	242		
Average,	......	.....	......	....	....	......	19.1	4.93
Wide ration.								
Concentrated foods: corn, 14; pea meal, 4½,	18½	2	1	Dec. 21 to Jan. 21.	869	165	19.8	3.72
Coarse fodders. clover rowen, 9; silage, 17,	26				1,034			
Concentrated foods; corn, 17; pea meal, 5½,	22½	2	2	Jan. 21 to Feb. 21.	1,034	116	21.8	5.82
Coarse fodders: clover rowen, 9; silage, 12,	21				1,150			
Total,	......	.....	......	....	....	281		
Average,	......	.....	......	....	....	......	20.8	4.77

Description of Experiments with Lambs of the Third Lot.—The lambs in this test consisted of a lot of 200 selected from a carload of feeding lambs bought in Chicago, November 17, 1897. They arrived in Middlefield, Conn., on November 20, having been three days in transit. They were what are called "natives" in Chicago. Nearly all of them had black or smut faces, and apparently carried quite a proportion of the blood of the "down" breeds. They were considered good feeders. The lambs were sheared a few days after arrival, and clipped an average of 3¾ pounds of medium wool per lamb. The lot of 200 lambs averaged 73½ pounds each in weight when the experiment began, December 1, 1897. During the ten days previous, while they were being "put on to their feed," they gained an average of nearly five pounds each above their weight in Chicago.

There were three feeding periods in the test, of 15, 16, and

17 days each, and the rations fed during the three periods varied slightly. The feeding stuffs used in this test were similar to those used in tests 1 and 2. The amount and proportions of the clover rowen and corn silage were nearly the same throughout the three periods. Any feed left in the racks was removed after a reasonable length of time, re-weighed, and deducted. The amount of refuse feed, however, was very slight. At the start, corn and pea meal in equal parts were used. After the first two or three weeks it became evident that this was not a ration upon which the animals would continue to thrive and remain vigorous. Toward the end of the first period some of the lambs were becoming lame; and, on the whole, the lambs were not making good growth.

After feeding about ten days in the second period, a small proportion of wheat bran was added to the ration. The bran apparently was not added in sufficient quantities, and the gains made during this period were not equal to the gains made in the first period. During the third period there was added a larger proportion of wheat bran, making the ration one part each of pea meal and bran, with one and one-third parts of corn. This had a very beneficial effect, as seen by the large increase in weight during the third period.

The kinds and weights of feed and the total digestible nutrients fed per day during the three periods are shown in Table 44 beyond. The proportions of total dry matter and of digestible nutrients were estimated from average figures for composition and digestibility of the several kinds of food materials.

Cost of Producing 100 Pounds Gain in Live Weight. — At the beginning of the first period, December 1, the 200 lambs weighed 14,700 pounds, and their weight December 15 was 15,840 pounds, giving a gain of 1,140 pounds in 15 days, or at the rate of 5.7 pounds per lamb for the period.

The second feeding period was from December 16 to January 1, 16 days. Near the end of this period it became necessary to butcher four lambs that were losing the use of their limbs, and their live weight was taken and included in the total weights at the end of the experiment. The weight of 200 lambs on December 16, was 15,840 pounds. The weight of 200 lambs January 1 (including four killed during the period) was 16,530 pounds, showing a gain in 16 days of 690 pounds.

TABLE 44.—*Total weight of different feeding stuffs and of digestible nutrients in the daily rations fed to two hundred lambs of the third lot.*

Feeds used.	Total weight.	Dry matter.	Digestible nutrients. Protein.	Fat.	Carbo-hydrates.	Nutritive ratio.
Period I.	lbs.	lbs.	lbs.	lbs.	lbs.	
Corn,	167	144.3	9.69	5.18	108.88	
Pea meal,	167	149.5	28.06	1.00	86.51	
Clover rowen,	148	131.4	14.50	3.11	54.32	
Silage,	325	80.0	3.25	2.28	45.83	
		505.2	55.50	11.57	295.54	1 : 5.8
Period II.						
Corn,	181	156.4	10.50	5.61	118.01	
Pea meal,	138	123.5	23.18	0.83	71.48	
Bran,	9	7.9	1.07	0.25	3.47	
Clover rowen,	141	125.2	13.82	2.96	51.75	
Silage,	316	77.7	3.16	2.21	44.56	
		490.7	51.73	11.86	289.27	1 : 6.1
Period III. (196 lambs.)						
Corn,	132	114.0	7.66	4.09	86.06	
Bran,	100	88.1	11.90	2.80	38.50	
Pea meal,	100	89.5	16.80	0.60	51.80	
Clover rowen,	146	129.6	14.31	3.07	53.58	
Silage,	301	74.0	3.01	2.11	42.44	
		495.2	53.68	12.67	272.38	1 : 5.6
Digestible nutrients (calculated for ten lambs, 1 day).						
Period I.		25.3	2.78	.58	14.78	
Period II.		24.5	2.59	.59	14.46	
Period III.		25.3	2.74	.65	14.00	

The third feeding period comprised the first 17 days of January. During this period it became necessary to butcher two more lambs from the same cause as before, and by accident one died from rupture. The gains during this period were as follows: Weight of 196 lambs January 1, 1898, 16,255 pounds; weight of 196 lambs on January 18 (including two butchered and one died), 17,485 pounds; 196 lambs gained in 17 days 1,230 pounds. When reduced to a period of 15 days, this gives a gain of 1,085 pounds, or at the rate of 5.54 pounds per lamb. The experiment was not continued longer, as the lambs were as fat and as heavy as the market required.

In estimating the cost of the rations, hay has been valued at \$10 per ton, corn silage at \$3 per ton, corn at 38½c. per bushel (56 pounds), bran at \$15, and pea meal at \$13 per ton. The cost of producing 100 pounds of gain in live weight for the whole period was \$7.91, while in the third period the cost was \$4.85. In the first period the gain was made at the rate of 5.70 pounds, in the second period 3.24 pounds, and in the third period 5.54 pounds per lamb for uniform periods of 15 days.

The details of this experiment with the third lot of lambs are summarized in the following table:

TABLE 45.—*Pecuniary economy of different rations fed lot three.*

Daily ration.		Total No. of lambs.	Period.		Total weight of lambs at beginning and end of period.	Gain for period.	Cost of ration per day.	Total cost of producing 100 lbs. gain live weight.
Kinds and amounts of each.	Total weight.		No.	Duration.				
	lbs.			1897-8.	lbs.	lbs.		
Corn, 167: pea meal, 167, . Clover rowen, 148; silage, 325,	334 473	200	1	Dec. 1 to Dec. 16.	14,700 15,840	1,140	\$3.48	\$4.58
Corn, 181; pea meal, 138; bran, 9, ... Clover rowen, 141; silage, 316,	328 457	200	2	Dec. 16 to Jan. 1.	15,840 16,530	690	3.41	7.91
Corn, 132; pea meal, 100; bran, 100, ... Clover rowen, 146; silage, 301,	332 447	196	3	Jan. 1 to Jan. 16.	16,255 17,485	1,230	3.51	4.85

WHAT THE EXPERIMENTS AND OUR EXPERIENCE TEACH.

Taken together with our experience in feeding 2,000 to 4,000 lambs each winter, the experiments tend to show that a mixture of feeding stuffs so combined as to furnish a palatable and wholesome ration is of greater importance in feeding lambs than the chemical composition of the ration. Lambs, when first placed on a grain ration, will usually make rapid gains for a short time irrespective of the composition of the ration, but unless the ration is a palatable one and well suited for growth as well as fattening, the lambs will not continue to eat vigor-

ously, and the gains will soon be greatly reduced. Our experience has shown that wheat bran should constitute a considerable part of the ration if good gains are to be expected for periods of considerable length. This was well illustrated in feeding the 10 lambs designated as Lot 2. In the first period the gains were at the rate of 16.5 pounds per lamb per month of 31 days, while in the second period, although the ration was considerably larger, the gain was reduced to 11.6 pounds per lamb. The absence of bran in this ration, we feel, accounts in a great measure for the lower gains after the feeding had been continued for quite a time. In the case of Lot 1 the ration in the second period was somewhat heavier than in the first period, the change being mainly the substitution of bran for a part of the corn, and in this case the gains in the second period over those of the first were increased 3.2 pounds per lamb for the period of 31 days. The absence of bran from the ration in the case of lambs which are growing rapidly is very likely to occasion a weakness of the legs and a general lack of vigor.

It is desirable to induce the lambs to eat as large a grain ration as possible if rapid gains are to be expected. In order to do this the coarse fodder of the ration should be as wholesome and nutritious as possible. For a dry feed nothing has proven superior to clover hay in our experience. We have had a large experience in the use of silage in connection with lamb feeding, and have generally got satisfactory results from its use when the quality of the silage has been good. Only silage from well ripened corn will give satisfactory results. Such varieties should be grown as will mature suitable for seed in this climate, and the corn should not be harvested for silage until the ears are well ripened and a large part of the water has escaped from the stalks and leaves. Silage with a large amount of water is sour and is always poorly eaten by lambs.

The ration which in the long run has given us the most satisfactory results in feeding lambs is one very similar to that used in the third period with the large lot of lambs. A grain ration consisting of one-third corn, one-third bran, and one-third pea meal by weight, together with coarse fodder consisting of clover hay or clover rowen one part, and corn silage two parts, has, on the whole, given us very satisfactory returns.

ANALYSES OF FODDERS AND FEEDING STUFFS.

REPORTED BY W. O. ATWATER AND F. G. BENEDICT.

In connection with the work of the Station during the past year various materials used as food for animals have been analyzed. Some of these analyses were made in connection with studies of rations fed to milch cows and are included in this report, although the details of the investigations are reserved for future publication. Others were made in connection with the digestion experiments with sheep, and still others in connection with the field and plot experiments with different crops and fertilizers, referred to in other parts of this report. Many of the analyses of forage plants grown on the experimental plots and the feeding stuffs used in the digestion experiments were made during the year 1897-1898, but as the experiments to which they belonged were not discussed in the Report for 1897, they were reserved for publication in the present report. Besides the analyses of fodders and feeding stuffs many analyses of uneaten residue and of feces were made in connection with the sheep digestion experiments reported above. These analyses have already been given in connection with the details of the experiments and are not included in the following tables.

The methods of analyses were, in general, those recommended by the Association of Official Agricultural Chemists, though minor modifications have been found desirable.

The results of the analyses as calculated to water content at the time of sampling are given in Table 46, page 235. In this table the materials are grouped somewhat according to their water content at the time of taking the sample, as follows:

Green fodders, silage, cured hay and fodder, grain and milling by-products.

The percentage composition of the water-free substance (dry matter) is shown in Table 47, page 239. The fuel values per pound are caluculated according to the usage, which assumes that one-hundredth of a pound of protein or carbohydrates has a fuel value of 18.6; a hundredth of a pound of fat, 42.2 calories. It has been pointed out in previous reports, and we reiterate with emphasis, that these factors for fuel values are

in no sense to be regarded as accurately settled. Such calculations of fuel values afford an approximate method for comparing different foods and feeding stuffs with respect to the quantities of energy which they are capable of yielding to the body. But these figures do not give an exact measure of the nutritive effects of the food materials. Indeed, we think they are in some cases quite far from such a measure. The total energy in the different feeding stuffs as obtained by burning with the bomb calorimeter was also determined in many instances. The whole subject of fuel values and nutritive effects of materials used as the food of animals and man is now being studied by the Station.

Two sets of averages are given in Tables 46 and 47 beyond. The first is the average of the samples published for the first time in the present report. The second is the average of all analyses of similar materials made up to the present time in this laboratory.

DESCRIPTION OF SAMPLES.

The samples of feeding stuffs, the analyses of which are reported in the following tables, may be described as follows:

Green Fodders and Grasses.

1,967, 1,968, 1,969, 1,970. Brome grass (*Bromus inermis*). — Grown in the Station grass garden in 1898. Samples were taken July 2d, when just past bloom.

No. 1,967 was from a plot to which no fertilizer had been applied; growth, small, thin, pale in color, with little bottom growth.

No. 1,968 was from a plot which had dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds per acre. Growth, much like growth on plot without fertilizers. Thin, pale in color, but little bottom growth.

No. 1,969 was from a plot which had dissolved bone-black and muriate of potash at the same rate as 1,968, and, in addition, nitrate of soda at the rate of 160 pounds per acre. Growth, quite heavy, fair color, thick, and leafy.

No. 1,970 was from a plot which had dissolved boneblack and muriate of potash at the same rate as 1,968, and, in addition, nitrate of soda at the rate of 480 pounds per acre. Growth, dense, heavy growth, dark green color, thick and leafy.

1,856, 1,975, 1,855, 1,976, 1,857, 1,977, 1,858, 1,978. Meadow fescue (*Festuca elatior*). — Grown in the Station grass garden in 1897–1898. Samples 1,855, 1,856, 1,857, 1,858, were taken on June 25, 1897, when a little past full bloom. Samples 1,975, 1,976, 1,977, 1,978, were taken July 2, 1898, when just past bloom.

No. 1,856 and 1,975 were from plots which had no fertilizer. Growth for each season was much the same. Pale in color, thin and small, with very little leaf and bottom growth.

Nos. 1,855 and 1,976 were from plots which had dissolved boneblack at the rate of 320 pounds per acre, and muriate of potash at the rate of 160 pounds per acre. Growth, slightly heavier yield than on plots with no fertilizer but grass, pale in color, thin and not leafy.

Nos. 1,857 and 1,977 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,855, and, in addition, nitrate of soda at the rate of 160 pounds per acre. Growth, fair in color, heavy growth both seasons, not as dense and leafy as on plot with largest amount of nitrogen.

Nos. 1,858 and 1,978 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,855, and, in addition, nitrate of soda at the rate of 480 pounds per acre. Growth, very heavy, dark green in color, dense leafy growth, with an especially heavy bottom growth.

1,852, 1,963, 1,851, 1,964, 1,853, 1,965, 1,854, 1,966. Orchard grass (*Dactylis glomerata*). — Grown in Station grass garden in 1897 and 1898. Samples 1,852, 1,851, 1,853, 1,854, were taken on June 19, 1897, when a little past full bloom.

Samples 1,963, 1,964, 1,965, 1,966, were taken on June 21, 1898, when just past bloom.

Nos. 1,852 and 1,963 were from a plot which had no fertilizer. Growth, much the same each season, thin, very pale in color, with small amount of bottom growth.

Nos. 1,851 and 1,964 were from plots which had dissolved boneblack at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds per acre. Growth, a little heavier each season than on nothing plots, color pale, and bottom growth light.

Nos. 1,853 and 1,965 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,851, and, in addition, nitrate of soda at the rate of 160 pounds per acre. Growth, much alike each season. Quite heavy, fair color, bottom growth thick.

Nos. 1,854 and 1,966 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1851 and, in addition, nitrate of soda at the rate of 480 pounds per acre. Growth, very heavy each season, 3½ to 4 ft. tall, very dense bottom growth, rich green color.

1,860, 1,859, 1,861, 1,862. Red top (*Agrostis vulgaris*). — Grown in the Station grass garden in 1897. The samples were taken July 24, 1897, in early seed stage, somewhat browned by recent heavy rains.

No. 1,860 was from a plot which had no fertilizer. Growth, small, thin, and spindled, pale in color.

No. 1,859 was from a plot which had dissolved boneblack at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds per acre. Growth, a little heavier than on nothing plot, pale in color, small amount of bottom growth.

No. 1,861 was from a plot which had dissolved boneblack and muriate of potash at the same rate as 1,859, and, in addition, nitrate of soda at the rate of 160 pounds per acre. Growth, fair in color, medium heavy with leafy bottom growth.

No. 1,862 was from a plot which had dissolved boneblack and muriate of potash at the same rate as 1,859, and, in addition, nitrate of soda at the rate of 480 pounds per acre. Growth, heavy, rich green in color, dense bottom growth.

1,848, 1,971, 1,847, 1,972, 1,849, 1,973, 1,850, 1,974. Timothy (*Phleum pratense*). — Grown in the Station grass garden in 1897 and 1898. Samples 1,848, 1,847, 1,849, 1,850, were taken on July 15, 1897, in the early seed stage. Samples 1,971, 1,972, 1,973, 1,974, were taken on July 11, 1898, when just past bloom.

Nos. 1,848 and 1,971 were from plots which had no fertilizer. Growth, thin and pale in color, uneven and small with little bottom growth.

Nos, 1,847 and 1,972 were from plots to which was applied dissolved boneblack at the rate of 320 pounds to the acre and muriate of potash at the rate of 160 pounds per acre. Growth, a little heavier than where no fertilizer was used, color pale, slender, and not leafy.

Nos. 1,849 and 1,973 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,847, and, in addition, nitrate of soda at the rate of 160 pounds per acre. Growth, quite heavy, fair color, medium amount of leaf growth.

Nos. 1,850 and 1,974 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,847, and, in addition, nitrate of soda at the rate of 480 pounds per acre. Growth, very heavy and dense, dark green in color and very leafy.

1,872, 1880, 6,002, 6,003, 1,871, 1,876, 6,004, 6,005, 1,879, 6,006, 1,878, 6,007, 1,877, 6,008, 1,875, 6,009, 1,874, 6,010, 1,873, 6,011. Cow pea fodder. — Grown by the Station in 1897 and 1898 as part of a special nitrogen experiment. For a description of the experiment see pages of this Report. Samples 1,871 to 1,880 inclusive were taken on September 28, 1897. At this time there was a full growth of fodder with a few seed pods formed. Samples 6,002 to 6,011 inclusive were taken on October 4, 1898.

Nos. 1,872, 1,880, 6,002, and 6,003 were from a plot which had no fertilizer.

Nos. 1,871, 1,876, 6,004, and 6,005, were from plots which had dissolved boneblack at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds per acre.

Nos. 1,879 and 6,006 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,871, and, in addition, nitrate of soda at the rate of 160 pounds per acre.

Nos. 1,878 and 6,007 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,871, and, in addition, nitrate of soda at the rate of 320 pounds per acre.

Nos. 1,877 and 6,008 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,871, and in addition nitrate of soda at the rate of 480 pounds per acre.

Nos. 1,875 and 6,009 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,871, and in addition sulphate of ammonia at the rate of 120 pounds per acre.

Nos. 1,874 and 6,010 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,871, and in addition sulphate of ammonia at the rate of 240 pounds per acre.

Nos. 1,873 and 6,011 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,871, and in addition sulphate of ammonia at the rate of 360 pounds per acre.

1,913, 1,914. Barley and pea fodder.— Used in sheep digestion experiment No. 49. The samples were taken October 15, 1897, and October 19, 1897, respectively.

There was but a light crop of barley with seed partially formed. Peas had but a few pods formed and the vines were small.

1,915, 1,916. Barley fodder.— Used in sheep digestion experiment No. 50. No. 1,915, sampled October 15, 1897, light crop ; seed beginning to form. No. 1,916, sampled October 19, 1897, light crop, seed partially formed.

1,881, 1,882. Oat and pea fodder.— Used in sheep digestion experiment No. 46. The samples were taken July 17 and 24, 1897. In the first sample (July 17) the oat seeds were formed, but quite soft, peas nearly out of bloom with many seeds partially formed. In the second sample (July 24) the oat seeds were quite firm and most of the peas were seeded.

1,883, 1,884, 6,001. Soy bean fodder.— Used in sheep digestion experiment No. 47. 1,883 and 1,884 were sampled August 28 and September 1, 1897. Condition of growth about the same for each sample. At the time the samples were taken the fodder was well grown and most of pods and many seeds were developed.

No. 6,001. Green soy bean fodder.— October 3, 1898. Most of the seed well ripened. Vines beginning to die at bottom. Heavy growth.

1,885, 1,886. Sweet corn fodder.— "Branching Sweet" variety. Used in sheep digestion experiment No. 48. Sampled September 17 and September 20, 1897, when seed was somewhat firm, but fodder still quite succulent.

2,000. Ensilage corn (Ohio white dent). October 3, 1898. Seed well ripened. Stalks with many of lower leaves dead.

Ensilage.

1,922, 1,927, 1,980, 2,000. Corn ensilage.— 1,922, 1,927 analyzed in connection with cow-feeding experiments. 1,980 from Storrs College. Sampled February 18, 1898. 2,000 (see page above).

Cured Fodders and Hays.

1,979, 1,983. Corn stover.— From Storrs College. Sampled February 10 and April 4, 1898.

1,921. Hay clover, rowen.

1,933. Hay clover (¼ grasses).

1,984-1,999. Hungarian Hay.— From pot experiments Nos. 13-28. Harvested September 3, 1898.

1,926, 1,932, 1,934, 1,937, 1,938, 1,939. Hay (mixed grasses).— Analyzed in connection with cow-feeding experiments.

1,940. Rowen hay.— Used in digestion experiment No. 51. Mixed grasses nearly free from clover; harvested in good condition.

1,942, 1,943, 1,982. Fine rowen hay (mixed grasses). Used in sheep digestion experiments Nos. 52, 53, and 54, respectively.

1,981. Rowen hay.—From Storrs College. Sampled Feb. 10, 1898.

1,931. Hay (second quality).— Used in cow-feeding experiment.

MILLING AND BY-PRODUCTS.

1,928. Chicago gluten meal.— Used in cow-feeding experiment.

1,960, 1,961. Chicago gluten meal.— From Storrs College.

1,935. Cleveland flax meal.— Used in cow-feeding experiment.

1,925, 1,929, 1,936. Cotton-seed meal.— Used in cow-feeding experiments.

1,957, 1,962. Cotton-seed meal.— From Storrs College.

1,924. Quaker oat feed.— Used in cow-feeding experiment.

1,944. Quaker oat feed.—Used in sheep digestion experiment No. 54.

1,923, 1,930. Wheat bran.— Used in cow-feeding experiments.

1,958, 1,959. Wheat bran.— From Storrs College.

1,836-1,845 and 6,012-6021. Soy beans.— Grown by the Station in 1897 and 1898, as part of a special nitrogen experiment.

1,836, 1,837, 6,012, 6,013 were from plots which had no fertilizer.

1,838, 1,839, 6,014, 6,015 were from plots which had dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds per acre.

1,840, 6,016 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,838, and in addition nitrate of soda at the rate of 160 pounds per acre.

1,841, 6,017 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,838, and in addition nitrate of soda at the rate of 320 pounds per acre.

1,842, 6,018 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,838, and in addition nitrate of soda at the rate of 480 pounds acre.

1,843, 6,019 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,838, and in addition sulphate of ammonia at the rate of 120 pounds per acre.

1,844, 6,c20 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,838, and in addition sulphate of ammonia at the rate of 240 pounds per acre.

1,845, 6,021 were from plots which had dissolved boneblack and muriate of potash at the same rate as 1,838, and in addition sulphate of ammonia at the rate of 360 pounds per acre.

1,846. Four o'clock seed.— From John V. Oberhaltze, Esmeralda, Florida. Sent through Department of Agriculture, Washington, D. C. The whole seed, including both kernel and hulls, was analyzed.

TABLE 46.—*Composition of fodders and feeding stuffs analyzed 1897-98. Calculated to water content at time of taking sample.*

Laboratory No.	Feeding stuffs.	Water.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Fuel value per pound.
	Green fodders.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
1,967	Bromus inermis, . .	61.1	3.2	1.3	19.1	12.4	2.9	700
1,968	" " . .	63.6	3.0	1.2	18.0	11.2	3.0	650
1,969	" " . .	64.7	2.8	1.1	17.5	11.3	2.6	635
1,970	" " . .	71.4	3.6	1.1	12.3	9.4	2.2	515
	Average (4),	**65.2**	**3.1**	**1.2**	**16.7**	**11.1**	**2.7**	**625**
	Average all analyses (8),	**65.6**	**3.2**	**1.2**	**16.9**	**10.4**	**2.7**	**615**
1,856	Meadow fescue, . .	63.8	2.3	.9	16.0	14.6	2.4	650
1,975	" " . .	61.0	2.6	1.0	20.6	12.3	2.5	700
1,855	" " . .	65.2	2.1	.9	16.7	12.4	2.7	620
1,976	" " . .	64.7	2.4	.9	17.4	11.9	2.7	630
1,857	" " . .	67.8	2.5	.9	15.1	11.4	2.3	575
1,977	" " . .	64.7	2.5	1.1	17.7	11.5	2.5	635
1,858	" " . .	72.1	3.3	1.0	12.0	9.4	2.2	500
1,978	" " . .	74.4	3.0	1.0	11.6	7.8	2.2	460
	Average (8),	**66.7**	**2.6**	**1.0**	**15.9**	**11.4**	**2.4**	**600**
	Average all analyses (22),	**69.8**	**2.6**	**1.0**	**14.0**	**10.3**	**2.3**	**545**
1,852	Orchard grass, ...	64.1	2.8	1.1	16.9	12.1	3.0	640
1,963	" "	68.9	1.9	1.1	15.0	11.0	2.1	565
1,851	" "	62.8	2.5	1.1	16.5	13.9	3.2	660
1,964	" "	68.9	2.0	1.0	14.5	11.2	2.4	555
1,853	" "	68.8	2.7	.9	14.3	10.5	2.8	550
1,965	" "	73.3	2.2	1.0	12.1	8.9	2.5	475
1,854	" "	70.3	3.9	1.2	11.8	10.2	2.6	530
1,966	" "	77.2	2.5	.9	9.9	7.5	2.0	410
	Average (8),	**69.3**	**2.5**	**1.0**	**13.9**	**10.7**	**2.6**	**545**
	Average all analyses (24),	**68.9**	**2.8**	**1.2**	**13.7**	**10.7**	**2.7**	**555**
1,860	Red top, ...	48.8	3.6	1.7	26.5	16.0	3.4	930
1,859	"	57.5	2.8	1.4	21.7	13.5	3.1	765
1,861	"	53.8	2.9	1.4	25.4	13.9	2.6	845
1,862	"	56.6	3.9	1.3	22.7	13.1	2.4	795
	Average (4),	**54.2**	**3.3**	**1.4**	**24.1**	**14.1**	**2.9**	**830**
	Average all analyses (8),	**57.1**	**3.2**	**1.4**	**22.6**	**12.9**	**2.8**	**780**
1,848	Timothy, ...	60.0	2.4	1.1	19.5	15.0	2.0	735
1,971	"	60.2	3.0	1.2	19.9	13.6	2.1	730
1,847	"	61.1	2.4	1.2	20.3	12.7	2.3	710
1,972	"	62.1	2.5	1.1	18.6	13.4	2.3	685
1,849	"	64.4	2.0	1.0	17.7	13.0	1.9	650
1,973	"	63.9	2.7	1.0	16.2	14.1	2.1	655
1,850	"	64.7	2.6	1.1	16.4	13.0	2.2	640
1,974	"	63.8	3.3	1.2	17.5	12.3	1.9	665
	Average (8),	**62.5**	**2.6**	**1.1**	**18.3**	**13.4**	**2.1**	**685**
	Average all analyses (24),	**66.6**	**2.6**	**1.0**	**16.3**	**11.5**	**2.0**	**605**
1,872	Cow pea fodder, . .	81.5	4.0	.8	6.9	4.3	2.5	315
1,880	" " . .	81.1	3.4	.6	8.3	4.4	2.2	325
6,002	" " . .	81.1	3.1	.6	9.2	4.3	1.7	335
6,003	" " . .	81.1	3.4	.6	8.7	4.1	2.1	325

TABLE 46.—CONTINUED.

Laboratory No.	Feeding stuffs.	Water.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Fuel value per pound.
	Green fodders.	Per ct.	Per ct.	Per ct.	Per ct	Per ct.	Per ct.	Calories.
1,871	Cow pea fodder, . .	83.8	3.1	.5	7.3	3.6	1.7	280
1,876	" " . .	83.2	3.0	.4	7.3	4.3	1.8	290
6,004	" " . .	82.7	3.1	.5	7.9	4.2	1.6	305
6,005	" " . .	84.1	3.1	.4	6.7	4.0	1.7	275
1,879	" " . .	82.2	3.2	.5	7.8	4.5	1.8	310
6,006	" " . .	81.9	3.0	.5	8.8	4.4	1.4	320
1,878	" " . .	82.2	3.4	.5	8.0	4.1	1.8	310
6,007	" " . .	82.5	3.0	.6	8.0	4.5	1.4	315
1,877	" " . .	82.9	3.1	.4	7.5	4.3	1.8	295
6,008	" " . .	81.4	3.3	.7	8.9	4.2	1.5	335
1,875	" " . .	83.5	3.1	.5	7.1	3.9	1.9	285
6,009	" " . .	82.1	3.0	.6	8.1	4.5	1.7	315
1,874	" " . .	82.8	2.7	.6	8.1	3.9	1.9	300
6,010	" " . .	83.0	3.1	.4	7.5	4.3	1.7	295
1,873	" " . .	82.0	4.1	.6	7.1	4.2	2.0	310
6,011	" " . .	83.2	2.9	.5	7.8	3.9	1.7	295
	Average (20),	**82.4**	**3.2**	**.5**	**7.9**	**4.2**	**1.8**	**305**
	Average all analyses (67),	**82.8**	**3.1**	**.6**	**7.7**	**3.9**	**1.9**	**300**
1,913	Barley and pea fodder, .	75.4	4.0	1.0	12.1	5.7	1.8	450
1,914	" " .	74.1	4.0	.9	12.7	6.2	2.1	465
	Average (2),	**74.7**	**4.0**	**1.0**	**12.4**	**5.9**	**2.0**	**455**
	Average all analyses (9),	**79.4**	**3.7**	**.8**	**9.1**	**5.2**	**1.8**	**370**
1,915	Barley fodder, . . .	73.0	3.1	.8	15.1	6.0	2.0	485
1,916	" " . . .	71.3	3.2	.9	16.0	6.6	2.0	520
	Average (2),	**72.1**	**3.2**	**.9**	**15.5**	**6.3**	**2.0**	**505**
	Average all analyses (6).	**75.2**	**3.4**	**.9**	**12.0**	**6.5**	**2.0**	**445**
1,881	Oat and pea fodder, . .	74.4	2.8	1.0	12.0	7.9	1.9	465
1,882	" " . .	74.3	3.2	.9	11.7	7.8	2.1	460
	Average (2),	**74.3**	**3.0**	**1.0**	**11.8**	**7.9**	**2.0**	**465**
	Average all analyses (9),	**78.7**	**3.5**	**1.0**	**9.1**	**6.0**	**1.7**	**390**
1,883	Soy bean fodder, . .	77.0	3.4	.7	10.4	6.3	2.2	405
1,884	" " . .	76.4	3.7	.7	11.0	6.1	2.1	415
6,001	" " . .	73.2	5.3	2.3	9.3	7.8	2.1	515
	Average (3),	**75.6**	**4.1**	**1.2**	**10.3**	**6.7**	**2.1**	**445**
	Average all analyses (16),	**76.3**	**3.7**	**1.0**	**10.2**	**6.5**	**2.3**	**420**
1,885	Sweet corn fodder, . .	78.5	1.9	.6	14.1	3.7	1.2	390
1,886	" " . .	76.6	1.7	.7	16.2	3.6	1.2	430
	Average (2),	**77.5**	**1.8**	**.7**	**15.1**	**3.7**	**1.2**	**410**
	Average all analyses (8),	**80.0**	**1.8**	**.6**	**12.3**	**4.1**	**1.2**	**365**
2,000	Ensilage corn, . . .	72.1	2.5	.8	17.1	5.9	1.6	510
	Ensilage.							
1,922	Corn ensilage, . . .	79.1	1.7	.6	10.4	7.1	1.1	380
1,927	" " . . .	79.5	1.7	.6	10.0	6.8	1.4	370
1,980	" " . . .	66.4	3.0	1.3	22.1	5.7	1.5	630
	Average (3),	**75.0**	**2.1**	**.8**	**14.2**	**6.6**	**1.3**	**460**
	Average all analyses (21),	**74.7**	**2.0**	**.9**	**14.8**	**6.2**	**1.4**	**465**

TABLE 46.—CONTINUED.

Laboratory No.	Feeding stuffs.	Water.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Fuel value per pound.
	Cured fodders and hays.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
1,979	Corn stover, . . .	27.1	4.9	1.4	36.1	23.7	6.8	1,260
1,983	" " . . .	13.9	5.9	2.7	46.3	23.5	7.7	1,520
	Average (2),	**20.5**	**5.4**	**2.0**	**41.2**	**23.6**	**7.3**	**1,390**
	Average all analyses (180),	**40.8**	**3.7**	**1.2**	**30.2**	**20.3**	**3.8**	**1,060**
1,921	Hay, clover rowen, . .	16.4	11.8	2.5	34.4	29.4	5.5	1,510
1,933	Hay, clover, ¼ grasses, .	8.5	13.5	3.0	42.3	26.2	6.5	1,650
	Average (2),	**12.5**	**12.6**	**2.8**	**38.3**	**27.8**	**6.0**	**1,580**
	Average all analyses (8),	**11.5**	**14.8**	**3.3**	**38.9**	**24.9**	**6.6**	**1,600**
1,984	Hay, Hungarian, . .	7.8	6.6	4.3	51.6	23.5	6.2	1,700
1,985	" " . .	7.5	6.9	4.4	50.5	24.2	6.5	1,705
1,986	" " . .	7.0	6.9	3.7	51.2	24.7	6.5	1,695
1,987	" " . .	7.9	7.1	3.6	51.6	23.5	6.3	1,680
1,988	" " . .	6.5	8.7	4.1	55.3	20.5	4.9	1,745
1,989	" " . .	6.6	8.8	4.0	54.5	21.2	4.9	1,740
1,990	" " . .	6.2	8.4	4.3	54.0	22.3	4.8	1,755
1,991	" " . .	5.7	8.4	4.0	52.4	24.5	5.0	1,755
1,992	" " . .	6.3	10.4	4.3	51.9	21.6	5.5	1,745
1,993	" " . .	5.7	11.6	4.0	51.5	21.8	5.4	1,750
1,994	" " . .	5.8	11.1	4.0	51.7	21.6	5.8	1,740
1,995	" " . .	5.5	11.6	3.7	51.7	21.7	5.8	1,740
1,996	" " . .	5.1	13.1	4.1	48.9	22.5	6.3	1,745
1,997	" " . .	5.4	12.1	3.9	50.3	22.1	6.2	1,735
1,998	" " . .	5.8	12.0	4.0	50.2	22.1	5.9	1,735
1,999	" " . .	5.8	11.3	4.0	50.4	22.6	5.9	1,735
	Average (16),	**6.3**	**9.7**	**4.0**	**51.7**	**22.5**	**5.8**	**1,730**
	Average all analyses (33),	**16.5**	**8.2**	**3.2**	**43.9**	**22.6**	**5.6**	**1,525**
1,926	Hay, mixed grasses, . .	8.8	6.1	2.3	45.4	33.1	4.3	1,670
1,932	" " . .	15.6	9.8	2.3	36.0	31.2	5.1	1,530
1,934	" " . .	8.9	8.3	2.3	47.3	28.9	4.3	1,670
1,937	" " . .	8.8	11.4	2.6	40.8	30.7	5.7	1,650
1,938	" " . .	6.6	13.7	2.9	40.2	29.4	7.2	1,670
1,939	" " . .	5.6	12.3	2.7	42.6	30.7	6.1	1,705
	Average (6),	**9.0**	**10.3**	**2.5**	**42.1**	**30.7**	**5.4**	**1,650**
	Average all analyses (42),	**11.7**	**8.1**	**2.9**	**43.8**	**28.1**	**5.4**	**1,610**
1,940	Hay, fine rowen, . .	12.0	15.3	3.5	37.7	25.1	6.4	1,600
1,942	" " . .	11.5	15.3	3.3	37.6	25.7	6.6	1,600
1,943	" " . .	10.7	16.0	3.8	31.9	30.6	7.0	1,620
1,981	" " . .	10.2	12.3	3.5	41.4	24.9	7.7	1,610
1,982	" " . .	6.7	13.4	4.2	41.0	27.3	7.4	1,695
	Average (5),	**10.2**	**14.5**	**3.7**	**37.9**	**26.7**	**7.0**	**1,665**
	Average all analyses (15),	**13.1**	**14.0**	**3.7**	**38.3**	**24.4**	**6.5**	**1,585**
1,931	Hay, second quality, .	13.8	11.0	2.6	34.8	32.0	5.8	1,555
	Average all analyses (5),	**12.4**	**9.3**	**2.9**	**41.7**	**28.1**	**5.6**	**1,595**
	Milling and by-products.							
1,928	Chicago gluten meal, . .	9.1	38.1	2.7	46.9	2.1	1.1	1,735
1,960	" " . .	8.3	36.9	3.7	48.1	1.9	1.1	1,775
1,961	" " . .	9.5	36.7	3.8	47.2	1.7	1.1	1,755
	Average (3),	**9.0**	**37.2**	**3.4**	**47.4**	**1.9**	**1.1**	**1,755**
	Average all analyses (13),	**8.8**	**36.6**	**5.8**	**45.3**	**2.5**	**1.0**	**1,815**

TABLE 46.—CONTINUED.

Laboratory No.	Feeding stuffs.	Water.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Fuel value per pound.
	Milling and by-products.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
1,935	Cleveland flax meal, . .	9.2	38.4	2.6	33.1	12.3	4.4	1,670
1,925	Cottonseed meal, . .	8.9	45.1	11.5	20.7	6.9	6.9	1,835
1,929	" " . .	6.9	48.2	14.4	16.8	7.3	6.4	1,955
1,936	" " . .	7.0	52.0	11.3	18.2	5.6	5.9	1,885
1,957	" " . .	6.6	48.4	11.7	21.7	5.0	6.6	1,890
1,962	" " . .	8.2	47.6	10.8	21.8	5.0	6.6	1,840
	Average (5),	**7.5**	**48.3**	**11.9**	**19.8**	**6.0**	**6.5**	**1,880**
	Average all analyses (21),	**7.0**	**44.4**	**11.8**	**25.8**	**4.3**	**6.7**	**1,885**
1,924	Quaker oat feed, . .	6.7	13.5	4.2	56.9	13.3	5.4	1,735
1,944	" " . .	7.9	9.2	2.2	54.5	20.7	5.5	1,660
	Average (2),	**7.3**	**11.4**	**3.2**	**55.7**	**17.0**	**5.4**	**1,700**
1,923	Wheat bran, . . .	7.7	16.2	4.8	52.8	11.4	7.1	1,700
1,930	" . . .	9.5	20.1	4.7	48.9	10.5	6.3	1,675
1,958	" . . .	11.1	15.5	4.6	50.9	10.9	7.0	1,630
1,959	" . . .	11.2	15.7	4.2	50.6	11.6	6.7	1,625
	Average (4),	**9.9**	**16.8**	**4.6**	**50.8**	**11.1**	**6.8**	**1,660**
	Average all analyses (46),	**9.7**	**17.0**	**5.0**	**53.3**	**9.4**	**5.6**	**1,695**
1,836	Soy beans, . . .	5.5	36.0	17.2	28.4	8.3	4.6	2,075
1,837	" . . .	5.0	35.4	16.0	35.3	3.9	4.4	2,060
6,012	" . . .	6.8	41.2	17.9	25.3	3.7	5.1	2,060
6,013	" . . .	8.4	41.8	18.2	23.3	3.3	5.0	2,040
1,838	" . . .	4.9	36.4	17.0	32.4	4.2	5.1	2,075
1,839	" . . .	4.5	36.8	16.9	32.3	4.3	5.2	2,080
6,014	" . . .	8.2	38.8	19.4	25.2	3.1	5.3	2,065
6,015	" . . .	9.4	38.6	19.5	24.4	2.9	5.2	2,050
1,840	" . . .	3.7	36.2	17.5	33.0	4.5	5.1	2,110
6,016	" . . .	9.1	40.8	19.2	23.5	2.2	5.2	2,045
1,841	" . . .	3.6	36.6	17.6	29.9	6.6	5.7	2,100
6,017	" . . .	8.6	40.9	18.6	24.6	2.3	5.0	2,045
1,842	" . . .	3.8	36.6	18.2	31.7	4.5	5.2	2,120
6,018	" . . .	9.0	40.4	18.9	23.9	2.7	5.1	2,045
1,843	" . . .	2.8	40.3	17.9	29.5	4.4	5.1	2,135
6,019	" . . .	9.3	37.8	19.4	25.4	3.2	4.9	2,055
1,844	" . . .	3.7	40.4	17.5	29.0	4.3	5.1	2,110
6,020	" . . .	9.5	38.5	19.8	24.5	2.6	5.1	2,055
1,845	" . . .	4.6	40.2	17.2	28.0	4.5	5.5	2,075
6,021	" . . .	9.3	38.1	19.7	24.3	3.1	5.5	2,050
	Average (20),	**6.5**	**38.6**	**18.2**	**27.7**	**3 9**	**5.1**	**2,075**
	Average all analyses (35),	**8.3**	**36.8**	**18.4**	**27.2**	**3.7**	**5.6**	**2,035**
1,846	Four o'clock seed, . .	12.4	13.9	3.2	48.6	17.7	4.2	1,625

TABLE 47.—*Composition of water-free substance of fodders and feeding stuffs analyzed 1897-98.*

Laboratory No.	Feeding stuffs.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Fuel value per pound.
	Green fodders.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
1,967	Bromus inermis, . .	8.24	3.24	49.05	31.94	7.53	1,795
1,968	" " . .	8.24	3.31	49.35	30.86	8.24	1,785
1,969	" " . .	8.05	3.27	49.51	31.94	7.23	1,800
1,970	" " . .	12.56	3.87	43.16	32.74	7.67	1,810
	Average (4),	**9.27**	**3.42**	**47.77**	**31.87**	**7.67**	**1,800**
	Average all analyses (8),	**9.50**	**3.54**	**48.79**	**30.38**	**7.79**	**1,800**
1,856	Meadow fescue, . .	6.30	2.57	44.17	40.24	6.72	1,795
1,975	" " . .	6.75	2.53	52.79	31.60	6.33	1,800
1,855	" " . .	5.99	2.52	48.03	35.74	7.72	1,775
1,976	" " . .	6.85	2.68	49.29	33.58	7.60	1,780
1,857	" " . .	7.85	2.89	46.69	35.40	7.17	1,795
1,977	" " . .	7.03	3.01	50.29	32.58	7.09	1,800
1,858	" " . .	11.89	3.69	42.97	33.59	7.86	1,800
1,978	" " . .	11.80	4.12	45.30	30.27	8.51	1,795
	Average (8),	**8.06**	**3.00**	**47.44**	**34.12**	**7.38**	**1,795**
	Average all analyses (22),	**8.67**	**3.19**	**46.09**	**34.48**	**7.57**	**1,795**
1,852	Orchard grass, ...	7.90	2.99	46.98	33.87	8.26	1,780
1,963	" "	6.24	3.40	48.31	35.31	6.74	1,815
1,851	" "	6.83	2.90	44.32	37.31	8.64	1,765
1,964	" "	6.38	3.10	46.63	35.96	7.93	1,785
1,853	" "	8.78	2.80	45.74	33.83	8.85	1,760
1,965	" "	8.17	3.62	45.44	33.56	9.21	1,775
1,854	" "	13.01	3.89	39.80	34.41	8.89	1,785
1,966	" "	11.02	4.08	43.46	32.85	8.59	1,795
	Average (8),	**8.54**	**3.34**	**45.08**	**34.64**	**8.40**	**1,785**
	Average all analyses (24),	**9.34**	**3.95**	**43.85**	**34.16**	**8.70**	**1,790**
1,860	Red top, ...	7.08	3.21	51.79	31.32	6.60	1,815
1,859	"	6.58	3.29	50.97	31.78	7.38	1,800
1,861	"	6.33	3.04	54.95	29.99	5.69	1,825
1,862	"	9.13	2.92	52.23	30.19	5.53	1,825
	Average (4),	**7.28**	**3.12**	**52.48**	**30.82**	**6.30**	**1,815**
	Average all analyses (8),	**7.56**	**3.28**	**52.62**	**30.05**	**6.49**	**1,815**
1,848	Timothy, ...	5.93	2.78	48.81	37.51	4.97	1,835
1,971	"	7.57	3.14	49.93	34.17	5.19	1,840
1,847	"	6.26	3.03	52.12	32.77	5.82	1,820
1,972	"	6.71	2.83	49.09	35.29	6.08	1,810
1,849	"	5.64	2.81	49.82	36.46	5.27	1,825
1,973	"	7.48	2.80	44.92	38.97	5.83	1,815
1,850	"	7.26	2.97	46.52	37.00	6.25	1,815
1,974	"	9.07	3.30	48.27	34.02	5.34	1,840
	Average (8),	**6.99**	**2.96**	**48.69**	**35.77**	**5.59**	**1,825**
	Average all analyses (24),	**7.83**	**3.14**	**48.66**	**34.33**	**6.04**	**1,820**
1,872	Cow pea fodder, . .	21.69	4.14	37.37	23.35	13.45	1,705
1,880	" " . .	18.13	3.03	44.02	23.46	11.36	1,720
6,002	" " . .	16.26	3.17	48.52	22.99	9.06	1,765
6,003	" " . .	17.87	3.40	46.18	21.64	10.91	1,740

TABLE 47.—CONTINUED.

Laboratory No.	Feeding stuffs.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Fuel value per pound.
	Green fodders.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
1,871	Cow pea fodder, . .	19.25	3.12	44.77	22.24	10.62	1,735
1,876	" " . .	18.17	2.49	43.33	25.37	10.64	1,720
6,004	" " . .	17.98	2.91	45.50	24.50	9.11	1,760
6,005	" " . .	19.57	2.66	41.97	25.45	10.35	1,730
1,879	" " . .	17.68	2.86	43.82	25.38	10.26	1,735
6,006	" " . .	16.38	2.85	48.35	24.49	7.93	1,780
1,878	" " . .	19.03	2.64	45.33	22.87	10.13	1,735
6,007	" " . .	16.91	3.41	45.66	25.94	8.08	1,790
1,877	" " . .	18.43	2.55	43.72	24.95	10.35	1,725
6,008	" " . .	17.51	3.53	48.15	22.57	8.24	1,790
1,875	" " . .	18.43	2.99	43.13	23.94	11.51	1,715
6,009	" " . .	16.82	3.16	45.26	25.15	9.61	1,755
1,874	" " . .	15.91	3.63	47.08	22.49	10.89	1,745
6,010	" " . .	17.99	2.60	44.10	25.25	10.06	1,735
1,873	" " . .	22.79	3.37	39.35	23.34	11.15	1,730
6,011	" " . .	17.03	2.77	46.54	23.39	10.27	1,735
	Average (20),	**18.19**	**3.06**	**44.61**	**23.94**	**10.20**	**1,745**
	Average all analyses (67),	**18.12**	**3.36**	**44.64**	**22.74**	**11.14**	**1,730**
1,913	Barley and pea fodder, .	16.43	3.87	49.31	23.08	7.31	1,815
1,914	" " .	15.50	3.68	49.06	23.71	8.05	1,800
	Average (2),	**15.97**	**3.78**	**49.18**	**23.39**	**7.68**	**1,805**
	Average all analyses (9),	**18 32**	**3.99**	**43.78**	**24.92**	**8.99**	**1,785**
1,915	Barley fodder, . . .	11.68	2.97	55.75	22.31	7.29	1,795
1,916	" " . . .	11.28	2.95	55.78	22.99	7.00	1,800
	Average (2),	**11.48**	**2.96**	**55.77**	**22.65**	**7.14**	**1,795**
	Average all analyses (6),	**14.03**	**3.55**	**47.97**	**26.27**	**8.18**	**1,790**
1,881	Oat and pea fodder, . .	11.02	3.68	46.82	30.92	7.56	1,805
1,882	" " . .	12.59	3.55	45.43	30.43	8.00	1,795
	Average (2),	**11.80**	**3.61**	**46.13**	**30 68**	**7.78**	**1,800**
	Average all analyses (9),	**17.34**	**4.70**	**41.84**	**27.57**	**8.55**	**1,815**
1,883	Soy bean fodder, . .	14.96	2.94	45.27	27.48	9.35	1,755
1,884	" " . .	15.67	3.01	46.65	25.87	8.80	1,770
6,001	" " . .	19.83	8.42	34.52	29.25	7.98	1,910
	Average (3),	**16.82**	**4.79**	**42.15**	**27.53**	**8.71**	**1,810**
	Average all analyses (16),	**15.55**	**4.22**	**42.87**	**27.57**	**9.79**	**1,775**
1,885	Sweet corn fodder, . .	8.65	2.88	65.78	17.12	5.57	1,825
1,886	" " . .	7.43	3.03	69.28	15.22	5.04	1,835
	Average (2),	**8.04**	**2.95**	**67.53**	**16.17**	**5.31**	**1,830**
	Average all analyses (8),	**9.03**	**2.87**	**61.37**	**20.78**	**5.95**	**1,815**
2,000	Ensilage corn, . . .	8.99	2.67	61.26	21.35	5.73	1,815
	Ensilage.						
1,922	Corn ensilage, . . .	8.16	2.89	49.50	34.12	5.33	1,830
1,927	" . . .	8.24	2.93	48.74	32.97	7.12	1,795
1,980	" . . .	9.07	3.79	65.70	16.91	4.53	1,865
	Average (3),	**8.49**	**3.20**	**54.65**	**28.00**	**5.66**	**1,830**
	Average all analyses (21),	**8.05**	**3.51**	**56.89**	**25.80**	**5 75**	**1,835**

TABLE 47.—CONTINUED.

Laboratory No.	Feeding stuffs.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Fuel value per pound.
	Cured fodders and hays.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
1,979	Corn stover, . . .	6.68	1.87	49.57	32.57	9.31	1,730
1,983	" " . . .	6.86	3.14	53.83	27.25	8.92	1,770
	Average (2),	**6.77**	**2.50**	**51.70**	**29.91**	**9.12**	**1,750**
	Average all analyses (180),	**6.39**	**1.98**	**51.00**	**34.20**	**6.43**	**1,785**
1,921	Hay, clover rowen, . .	14.17	2.99	41.10	35.17	6.57	1,810
1,933	Hay, clover, ¼ grasses, .	14.69	3.31	46.22	28.64	7.14	1,805
	Average (2),	**14.43**	**3.15**	**43 66**	**31.90**	**6·86**	**1,805**
	Average all analyses (8),	**16.77**	**3.72**	**43.90**	**28.17**	**7.44**	**1,810**
1,984	Hay, Hungarian, . .	7.12	4.69	55.93	25.53	6.73	1,845
1,985	" " . .	7.42	4.76	54.65	26.15	7.02	1,840
1,986	" " . .	7.46	4.01	54.99	26.53	7.01	1,825
1,987	" " . .	7.67	3.95	56.05	25.54	6.79	1,825
1,988	" " . .	9.36	4.34	59.10	21.90	5.30	1,865
1,989	" " . .	9.37	4.32	58.38	22.65	5.28	1,865
1,990	" " . .	9.00	4.56	57.56	23.72	5.16	1,870
1,991	" " . .	8.95	4.22	55.57	25.98	5.28	1,860
1,992	" " . .	11.14	4.58	55.34	23.04	5.90	1,855
1,993	" " . .	12.26	4.22	54.66	23.07	5.79	1,850
1,994	" " . .	11.74	4.21	54.92	22.96	6.17	1,845
1,995	" " . .	12.24	3.91	54.73	22.97	6.15	1,840
1,996	" " . .	13.84	4.32	51.50	23.70	6.64	1,840
1,997	" " . .	12.82	4.17	53.17	23.31	6.53	1,835
1,998	" " . .	12.74	4.25	53.33	23.45	6.23	1,845
1,999	" " . .	12.00	4.28	53.47	23.95	6.30	1,845
	Average (16),	**10.32**	**4.30**	**55.21**	**24.03**	**6.14**	**1,845**
	Average all analyses (33),	**9.90**	**3.73**	**52.10**	**27.43**	**6.84**	**1,820**
1,926	Hay, mixed grasses, . .	6.63	2.51	49.83	36.30	4.73	1,830
1,932	" " . .	11.66	2.77	42.65	36.93	5.99	1,815
1,934	" " . .	9.12	2.47	51.91	31.73	4.77	1,830
1,937	" " . .	12.48	2.87	44.78	33.62	6.25	1,810
1,938	" " . .	14.63	3.13	42.99	31.51	7.74	1,790
1,939	" " . .	12.96	2.86	45.14	32.54	6.50	1,805
	Average (6),	**11.25**	**2.77**	**46.21**	**33.77**	**6.00**	**1,815**
	Average all analyses (42),	**9.14**	**3.30**	**49.63**	**31.87**	**6.06**	**1,825**
1,940	Hay, fine rowen, , .	17.37	3.96	42.81	28.52	7.34	1,815
1,942	" " . .	17.31	3.68	42.48	29.05	7.48	1,810
1,043	" " . .	17.93	4.21	35.72	24.25	7.89	1,810
1,981	" " . .	13.71	3.90	46.14	27.68	8.57	1,790
1,982	" " . .	14.32	4.47	43.92	29.31	7.98	1,815
	Average (5),	**16.13**	**4 04**	**42.22**	**29.76**	**7.85**	**1,810**
	Average all analyses (15).	**16.19**	**4.24**	**44.10**	**28.02**	**7.45**	**1,820**
1,931	Hay, second quality, .	12.78	3.05	40.41	37.09	6.67	1,810
	Average all analyses (5),	**10.58**	**3.29**	**47.58**	**32.06**	**6.49**	**1,820**
	Milling and by-products.						
1,928	Chicago gluten meal, . .	41.97	2.97	51.62	2.29	1.15	1,910
1,960	" " . .	40.22	4.02	52.47	2.10	1.19	1,930
1,961	" " . .	40.55	4.24	52.20	1.85	1.16	1,935
	Average (3),	**40.91**	**3 74**	**52.10**	**2.08**	**1.17**	**1,930**
	Average all analyses (13),	**40.18**	**6.29**	**49.70**	**2.73**	**1.10**	**1,990**

TABLE 47.—CONTINUED.

Laboratory No.	Feeding stuffs.	Protein.	Fat.	Nitrogen free extract.	Fiber.	Ash.	Fuel value per pound.
	Milling and by-products.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
1,935	Cleveland flax meal, . .	42.35	2.90	36.45	13.51	4.79	1,840
1,925	Cottonseed meal, . .	49.49	12.64	22.71	7.54	7.62	2,015
1,929	" " . .	51.75	15.49	18. 5	7.84	6.87	2,100
1,936	" " . .	55.93	12.10	19.58	6.06	6.33	2,025
1,957	" " . .	51.82	12.51	23.24	5.40	7.03	2,025
1,962	" " . .	51.82	11.71	23.72	5.50	7.25	2,000
	Average (5),	**52.16**	**12.89**	**21.46**	**6.47**	**7.02**	**2,035**
	Average all analyses (21),	**47.72**	**12.65**	**27.75**	**4.62**	**7.26**	**2,025**
1,924	Quaker oat feed, . .	14.47	4.47	61.01	14.28	5.77	1,860
1,944	" " . .	10.00	2.30	59.20	22.50	6.00	1,805
	Average (2),	**12.23**	**3.38**	**60.11**	**18.39**	**5.89**	**1,830**
1,923	Wheat bran, . . .	17.53	5.24	57.14	12.37	7.72	1,840
1,930	" . . .	22.22	5.20	54.03	11.57	6.98	1,850
1,958	" . . .	17.43	5.20	57.25	12.22	7.90	1,835
1,959	" . . .	17.68	4.77	56.99	13.00	7.56	1,830
	Average (4),	**18.72**	**5.10**	**56.35**	**12.29**	**7.54**	**1,840**
	Average all analyses (46),	**18.80**	**5.58**	**59.04**	**10.37**	**6.21**	**1,875**
1,836	Soy beans, . . .	38.14	18.16	30.07	8.75	4.88	2,195
1,837	" . . .	37.27	16.81	37.20	4.14	4.58	2,170
6,012	" . . .	44.21	19.21	27.15	4.00	5.43	2,210
6,013	" . . .	45.65	19.86	25.43	3.62	5.44	2,225
1,838	" . . .	38.32	17.88	34.07	4.38	5.35	2,180
1,839	" . . .	38.55	17.66	33.86	4.52	5.41	2,175
6,014	" . . .	42.23	21.16	27.46	3.42	5.73	2,250
6,015	" . . .	42.64	21.54	26.88	3.25	5.69	2,260
1,840	" . . .	37.58	18.13	34.33	4.64	5.32	2,185
6,016	" . . .	44.91	21.10	25.87	2.45	5.67	2,250
1,841	" . . .	38.00	18.25	31.07	6.80	5.88	2,180
6,017	" . . .	44.77	20.31	26.88	2.55	5.49	2,235
1,842	" . . .	38.09	18.95	32.98	4.61	5.37	2,205
6,018	" . . .	44.40	20.72	26.33	2.94	5.61	2,245
1,843	" . . .	41.45	18.41	30.31	4.58	5.25	2,195
6,019	" . . .	41.64	21.40	28.03	3.48	5.45	2,265
1,844	" . . .	41.93	18.22	30.15	4.47	5.23	2,190
6,020	" . . .	42.54	21.82	27.15	2.87	5.62	2,270
1,845	" . . .	42.12	18.00	29.33	4.73	5.82	2,175
6,021	" . . .	42.05	21.77	26.72	3.38	6.08	2,260
	Average (20),	**41.32**	**19.47**	**29.56**	**4.18**	**5.47**	**2,215**
	Average all analyses (35),	**40.16**	**20.01**	**29.66**	**4.04**	**6.13**	**2,220**
1,846	Four o'clock seed, . .	15.92	3.66	55.48	20.19	4.75	1,860

METEOROLOGICAL OBSERVATIONS.

REPORTED BY C. S. PHELPS.

The meteorological observations made under the directions of the Station during 1898 were similar to those of previous years. The Station equipment at Storrs consists of the ordinary instruments for observing temperatures, pressure of the air, humidity, rainfall, snowfall, and velocity of the wind. The instruments are similar to those in use by the United States Weather Service. In addition to the records made at Storrs, the rainfall for the summer season (May 1st to October 31st) has been recorded by eleven farmers in co-operation with the Station.

The total precipitation for the year (51.1 inches) was 5.3 inches above the average at Storrs for the past ten years, and about 3 inches above the general average for Connecticut, as computed from the records of all of the New England Meteorological Society's observers who have made observations covering periods of from five to thirty years. The rainfall was fairly well distributed throughout the year. Early in the season there was sufficient rain to give all crops a vigorous start, while during July and August there was a slight excess, but, on the whole, the moisture in the soil was about right to keep up a healthy and vigorous growth of all crops.

The temperature for January and February was about normal. March was unusually mild, so that some garden truck was planted and oats were sown. The temperature for April and May was unusually low, and the spring as a whole was rather backward. The last killing frost occurred on May 10th. The summer months were unusually warm and the weather conditions were favorable for nearly all crops. The hay crop was a heavy one and nearly all early-cut fields produced a large second crop. Light frosts occurred on low grounds September 13th and 14th, and more generally on September 21st and October 10th and 13th, but the first killing frost was on October 17th. The length of the growing season from the last killing frost in the spring to the first killing frost in the fall was 160 days. The average growing season at Storrs for the past eleven years has been 147 days.

The month of October was too wet for harvesting corn, and in many places the crop was considerably damaged.

The most phenomenal storm of the season was the snow storm of November 26-27th, which gave about one foot of snow on a level and produced drifts of from six to eight feet deep. Roads were blocked for three days, greatly delaying travel.

Through the kindness of the New England Meteorological Society we are able to publish the rainfall records from ten of their stations in Connecticut. Table 48 gives the rainfall as recorded for the six months ending October 31st for twenty-one localities in the State, and Table 49 gives the summary of observations made by the Station at Storrs.

TABLE 48.—*Rainfall during six months ending October 31, 1898.*

Locality.	Observer.	Inches per month.						
		May.	June.	July.	August.	September.	October.	Total.
Falls Village,	M. H. Dean,	6.35	2.99	2.23	8.22	3.73	3.74	27.26
Cream Hill,	C. L. Gold,	6.70	2.87	1.79	6.77	4.25	3.35	25.73
Winchester,	W. L. Wetmore,	4.45	2.40	2.92	6.90	2.80	4.40	23.87
Waterbury,	N. J. Welton,	6.86	.94	3.37	9.48	2.52	5.82	28.99
Norwalk,	G. C. Comstock,	8.53	.79	7.27	7.15	1.40	8.29	33.43
Southington,	Lumen Andrews,	5.56	.53	3.33	8.50	2.63	6.09	26.64
West Simsbury,	S. T. Stockwell,	6.18	2.23	4.59	7.38	2.07	4.99	27.44
Canton,	G. J. Case,	6.74	2.71	4.97	7.02	2.31	5.44	29.19
Hartford,	Prof. S. Hart,	6.05	2.40	5.15	7.58	2.86	6.32	30.36
Newington,	J. S. Kirkham,	6.23	1.35	3.66	6.18	3.41	4.59	25.42
New Haven,	Weather Bureau,	8.03	.21	5.03	6.55	2.30	7.22	29.34
Madison,	J. D. Kelsey,	8.12	.99	5.47	8.66	2.88	7.19	33.31
South Manchester,	K. B. Loomis,	5.53	1.48	5.78	6.68	2.83	6.91	29.21
New London,	Weather Bureau,	8.12	1.09	4.72	7.69	3.33	8.47	33.42
Colchester,	S. P. Willard,	6.16	.79	5.05	8.65	2.61	6.39	29.65
Gilead,	A. C. Gilbert,	5.86	1.58	4.97	8.02	2.81	5.94	29.18
Lebanon,	E. A. Hoxie,	6.08	2.40	7.28	8.40	1.85	5.25	31.26
North Franklin,	C. H. Lathrop,	6.23	1.89	6.84	7.69	3.22	6.21	32.08
Storrs,	Experiment Sta.,	3.81	2.48	6.24	5.87	2.22	6.18	26.80
Voluntown,	Rev. C. Dewhurst,	6.45	3.44	5.73	7.28	2.65	9.33	34.88
Clark's Falls,	E. D. Chapman,	5.15	1.25	6.67	6.66	2.11	11.01	32.85
Average,	. . . . . .	6.34	1.75	4.91	7.49	2.71	6.34	29.54

TABLE 49.— *Meteorological summary for 1898.*

[Observations made at Storrs, by the Station.]

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.	Total.
Highest barometer,	30.58	30.63	30.77	30.33	30.36	30.33	30.45	30.26	30.43	30.48	30.54	30.54	30.48	....
Lowest barometer,	29.29	29.06	29.86	29.52	29.65	29.50	29.72	29.75	29.69	29.44	29.25	29.32	29.50	....
Mean barometer,	30.00	30.07	30.23	29.95	29.98	30.00	30.05	30.00	30.06	30.12	30.03	30.04	30.04	....
Highest temperature,	51	51	62	70	81	87	96	88	90	85	61	53	73	....
Lowest temperature,	−7	−4	19	16	33	44	45	47	37	29	15	−4	23	....
Mean temperature,	25	28	40	42	54	64	70	69	63	52	38	29	48	....
Relative humidity,	....	....	....	68	76	75	79	53	79	83	....	....	....	....
Total precipitation,	4.70	4.03	3.09	4.44	3.81	2.48	6.24	5.87	2.22	6.18	6.11	1.96	....	51.13
No. of days with precipitation of .01 inch or more,	12	9	11	12	17	6	9	13	8	10	9	7	....	123
No. of clear days,	5	10	10	8	8	6	6	6	14	10	9	6	....	99
No. of fair days,	11	6	9	10	6	18	18	17	8	11	9	14	....	138
No. of cloudy days,	15	12	12	12	16	6	6	8	8	10	12	11	....	128
Total movement of wind in miles,	8,492	6,665	5,785	8,057	6,099	5,978	4,269	4,924	4,981	6,351	7,556	6,909	....	76,066
Maximum velocity of wind,	48	60	36	36	39	30	45	40	36	42	54	60	....	....

INDEX.